MORTALITY AMONG COAL MINERS COVERED BY THE UMWA HEALTH AND RETIREMENT FUNDS

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This report presents the results of a cause-specific mortality study of the U.S. coal mining industry in which mortality of U.S. coal miners is compared with that of the total U.S. male population. A cohort of 23,233 miners was investigated during the period June 30, 1973, through December 31, 1975. The study indicates that excessive mortality from accidents, several categories of respiratory diseases, and stomach cancer is apparent in the miner cohort. Mortality from lung cancer was found to be moderately higher in the miner cohort than in the total U.S. male population.

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PREFACE

This report is a summary of the analyses done under Contract Number HSM 99-73-80 during the contract period June 30, 1973 through December 31, 1975. The detailed examinations of the cause-specific mortality within the coal mining industry provide information as regards the mortality experience of the U.S. coal miner when compared to the total U.S. male population.

Any study such as this requires the co-operation and substantial input of many different people. I would like to acknowledge the co-operation of the United Mine Workers Health and Retirement Funds, without whom the study would not have been possible. In particular, from their group, I would like to thank Dr. John Newdorp, Mr. Mahlon Milburn, Mr. Bill Weeks, Mr. Henry Cortesini and their staffs who were very helpful during the long data collecting process. I would also like to acknowledge Mr. Don Eliot for answering my numerous questions on the interpretation of Fund records, and Mr. Stu Raykloff of the Research and Statistics Section for supplying information on pension dates and locations of various districts.

I would also like to acknowledge the following faculty members in the Department of Biostatistics: Dr. Carol Redmond for helpful discussions on the proper methodology of analysis for occupational mortality studies and Dr. Philip Enterline whose initial interest in the coal miners as an occupational group was instrumental in having a study of this type conducted.

During the data collection period, many students were involved in various clerical operations and in some cases were able to obtain partial financial support from this contract while continuing their education. In particular I would like to acknowledge the input of former student Mr. Bob Li and former student Mrs. Trudy Lerer, who is presently a senior research assistant in the Biostatistics department. In addition, Dr. Otto Wong, presently an assistant professor at Georgetown University, contributed substantially to Chapter I of the present report.

The following individuals and staff also provided invaluable contributions in the data collection, coding, computer processing, and preparation of the report: Mr. H. W. Rush, consultant; Miss Mary Preininger and Mr. Steve Sefcik, programmers; Mrs. Nancy Haberman, data processor; Miss Joan Marincek, keypuncher; and Mrs. Linda Kobus, secretary.

We wish also to acknowledge the efforts of Mrs. Marion Heid who reviewed and coded all of the death certificates.

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I. Literature Review and Historical Perspective

Although coal mining in Great Britain dates back to the year 852, the industry was confined to small operations until the early part of the eighteenth century with the manufacture of iron and the invention of the steam engine. The British medical literature of the 19th century contained numerous reports on lung diseases among coal miners. A detailed review of these reports was given by Meiklejohn in a series of papers (1, 2, 3). Only a brief summary of these reports will be given here. References to the original articles can be found in the above cited review.

Lung disease among the British coal miners was identified as a disease associated with coal mining in 1831 by Gregory, and he is the first author to do so in print. Three years later, Marshall noted that the disease was a consequence of the inhalation of fine coal mine dust and its deposition in the lungs. Furthermore, he asserted that conditions favorable to the disease occurred in "mines which had hard dry seams and where there was much pick work". In the subsequent years, based on the reports and the observations of physicians practicing in coal mining communities, it was generally agreed that the risk of developing such respiratory disease depended on the coal seam, the cutting process and the length of employment in coal mines. The disease was considered non-reversible and the only prevention was adequate ventilation in coal mines. After much controversy, it was also concluded that the disease involved some constitutional factor but was primarily the result of the

inhalation of the coal mine dust, that simple coal dust was comparatively harmless, and that stone dust was the real noxious factor.

Toward the latter part of the last century, conditions in the British coal mines improved considerably. In 1885, having observed the low death rates, especially from pulmonary disease, among coal miners, Smart proposed that "there must be some protective feature in coal mining operations, and that the preserving element might, after all, be the dust derived from the coal". This theory gained much support from Hirt, Cummins, Haldane and others. Instead, free crystalline silica from sandstone was held responsible for lung damage, and the entire emphasis was placed on silicosis.

In the year 1906 occupational mortality statistics were published by the Registrar General for the years 1890-92 and 1900-02. Thus, the knowledge that had been based up until this time only on the experience of practicing physicians could now be tested. These statistics indicated a decline in mortality for coal miners among all age groups and for all geographical regions. Despite these findings interest in the subject continued.

At the turn of this century, substantial changes took place inside the coal mines. The mines themselves had become deeper and more extensive. The progressive increase of machine mining contributed to a serious increase in dustiness, which more than offset the advantages of better ventilation. In the following years, conflicting opinions based on individual experiences were reported. However, even among those

who considered coal mining a hazardous occupation the emphasis continued to be placed on free crystalline silica.

Then, in 1928, based on an analysis of 426 deaths of coal trimmers in South Wales, Collis and Gilchrist (4) reported that the coal trimmers showed pneumoconiotic changes in their lungs, even though the coal which they shoveled had been washed relatively free of country rock, which was the true source of silica. Furthermore, the lungs yielded no abnormal amount of silica at autopsy. The basic role of coal dust in the development of pneumoconiosis among coal miners was thus established. This theory was to gain further support later from studies that indicated a high incidence of pneumoconiosis in electrotypers who were exposed to natural graphite containing very little free silica (5), and in carbon electrode makers who were exposed to silica-free carbon (6).

A more general view of the situation was made available in 1938, when the Registrar General published the occupational mortality statistics covering the period 1930-32. Although there was a fall in the mortality of the coal miners from all causes, the improvement was much less than that in the general population. It appeared that coal miners were not benefiting from public health improvement to the same extent as the rest of the population.

In the meantime, the Medical Research Council was asked by the Home Office and the Mines Department to investigate the problem of chronic pulmonary disease among coal miners. The findings were published in three separate reports in 1942, 1943 and 1945 (7).

In these reports, Hart and Aslett, based on lung changes among surface workers on the screens and coal trimmers at the docks, confirmed the importance of coal dust and not rock dust as a causative agent of pneumoconiosis. It was also discovered that the incidence of pneumoconiosis was not uniform throughout the different regions: it was high in the anthracite or hard coal area and low in the bituminous or soft coal area. These findings led Hart and Aslett to put forth the "Rank of Coal Hypothesis". The rank of coal refers to the chemical composition and is determined mainly by the amount of volatile matter. The range extends from anthracite with the highest rank on one end, through the medium rank bituminous, to lignite with the lowest rank on the other. According to the hypothesis, the incidence of pneumoconiosis increases with the rank of coal. In the same series of reports, the term "coal workers' pneumoconiosis" was introduced, a term which avoids the implication of silica.

As interest in occupational mortality increased, more statistics became available. In 1931 Henry, Kennaway and Kennaway (8) reported the results of a study relating cancer of the bladder and cancer of the prostate to various occupational groups. Death certificates were examined for all males who died from either of these two causes in England and Wales for the time period 1921-1928. Taking the population at risk as estimated by the National Census (1921) for each occupational group, they calculated the ratios of the "registered" deaths to the number of deaths that would be expected if the occupational group had the same rate as the total population. Their results indicated that coal miners did

not have an excess risk from bladder or prostate cancer, and in this respect, they were quite similar to agricultural workers who also had a lower number of cases than expected. The one exception to this low observed number among the various jobs associated with coal mining was the group "persons conveying material to the shaft". However, the authors felt that this was due primarily to lack of conformity between the descriptions of occupation given by the men themselves in the census and those obtained by the Registrar at the time of death.

Using the same approach, Kennaway and Kennaway examined the death certificates of males, aged 20 and over, who died from cancers of the lung and of the larynx in England and Wales from 1921 to 1938. The figures for the first 12 years (1921-1932) were published in an earlier paper, and those for the subsequent six years in a second report (9, 10). Table 1.1 gives the mortality ratios of the observed number of deaths to the expected number of deaths for the various occupational categories associated with coal mining.

TABLE 1.1

Deaths from Lung Cancer in Coal Miners, England and Wales, 1921-1938

COAL MINERS	1921-1932			1933-1938		
	Registered Deaths	Calculated Deaths	Ratio x 100	Registered Deaths	Calculated Deaths	Rat x 1
All coal miners	289	492.5	59	485	820.2	5
Hewers and getters	174	274.0	63	319	442.7	7
Other underground workers	28	65.2	44	52	112.4	4
Conveying material to shaft	12	31.4	38	28	60.2	4
Road making	29	54.8	53	37	100.0	3
Workers above ground	46	65.1	71	49	104.9	4

(From Kennaway and Kennaway 1936, 1947)

Thus, in every category of coal miners, there was a considerable deficit in mortality from lung cancer in both time intervals. The mortality ratio for all coal miners in both periods was 59.

Table 1.2 shows the corresponding figures in cancer of the larynx.

TABLE 1.2

Deaths from Larynx Cancer in Coal Miners
England and Wales, 1921-1938

COAL MINERS	1921-1932			1933-1938		
	Registered Deaths	Calculated Deaths	Ratio x 100	Registered Deaths	Calculated Deaths	Ratio x 100
All coal miners	257	484.1	53	182	277.6	66
Hewers and getters	150	260.0	58	107	146.0	73
Other underground workers	30	68.5	44	18	40.0	45
Conveying material to shaft	11	25.1	44	7	16.5	42
Road making	27	60.0	45	24	36.9	65
Workers above ground	39	70.5	55	26	38.2	68

(From Kennaway and Kennaway 1936, 1947)

Again, there was considerable deficit of mortality from larynx cancer in every category of coal miners. For all coal miners, the mortality ratio was 53 in 1921-1932, and 66 in 1933-1938. Although the observed numbers of deaths for coal miners were low for all the types of cancers considered in their series of papers, Kennaway and Kennaway are careful to point out the possible errors in the utilization of death certificates and census returns for statistical purposes.

In a later report, Kennaway and Kennaway investigated the possible influence of pneumoconiosis on the incidence of lung cancer among the

British coal miners, during the years 1937 to 1946 (11). The incidence of lung cancer was estimated by the same method employed in the previous studies. The prevalence of pneumoconiosis was estimated by the number of compensation cases arising under the Workmen's Compensation Acts. A comparison of incidence of lung cancer in different coalfields was made by dividing the number of employed (average of 1943-1946) by the number of deaths (1937-1946), and the result was stated as the number of persons required to produce one death. The authors maintain that this simple approach is adequate since the age distributions do not vary much for the different areas. It was found that the face workers had a higher incidence, in some coalfields up to three times, than the other coal workers. In general, coalfields with a high prevalence of pneumoconiosis tended to have a low incidence of lung cancer. However, this reciprocal relationship was not absolutely consistent throughout all coalfields.

In order to investigate the reciprocal relationship between pneumoconiosis and lung cancer proposed by Kennaway and Kennaway, James examined the results of the necropsies of 1827 coal workers and 1531 non-coal workers in South Wales during 1947-1952 (12). Of the 1827 miners, 967 had simple pneumoconiosis and 860 had massive fibrosis. Primary lung cancer was found in 49 (5.1%) of those with simple pneumoconiosis and in 12 (1.4%) of those with massive fibrosis. The 967 cases of simple pneumoconiosis were further divided into three groups showing respectively slight, moderate, and severe degrees of the condition. The results are given in Table 1.3.

TABLE 1.3

Distribution of Lung Cancer in 1827 Coal Miners
with Pneumoconiosis and in 1531 Non-miners in South Wales

	Simple Pneumoconiosis			Massive Fibrosis	All Miners	All Non-miners
	Slight	Moderate	Severe			
Number of Pneumoconiosis deaths	524	272	171	860	1827	1531
Lung Cancer deaths observed	31	11	7	12	61	82
Lung Cancer deaths expected based on all coal miners	17.5	9.1	5.7	28.7	61	51.0
Ratio x 100	177	121	122	42	100	161

(From James, 1955)

It can be seen that the ratio of observed to expected deaths from lung cancer diminished with increasing severity of pneumoconiosis and was least in those with massive fibrosis. This result led the author to conclude that early death from pneumoconiosis might be a factor in reducing the incidence of lung cancer in miners.

In connection with the possibility of a reciprocal relationship between pneumoconiosis and lung cancer among coal miners, the Registrar General's mortality report for 1949-1953 should also be mentioned (13). The standardized mortality ratios from both diseases were calculated for different coalfields in England and Wales.

The Standardized Mortality Ratio (SMR) from lung cancer were low in miners from Glamorgan and Monmouthsire, areas where pneumoconiosis was most common, but was equally low in miners from the West Riding and Durham areas, where pneumoconiosis was comparatively rare. Thus, the data failed to show any consistent relationship between the frequencies of the two diseases.

TABLE 1.4

S.M.R. from Lung Cancer and Pneumoconiosis in Coalfields in England and Wales 1949-53

Region	Lung Cancer SMR	Pneumoconiosis SMR
Glamorgan (anthracite)	64	∞
Glamorgan (other)	75	4814
Monmouthshire	57	1875
Durham	72	527
West Riding, Yorks	66	338
Cheshire and Lanes	72	880
North Staffs	106	1750
South Staffs, Worcs	75	1367

(From the Registrar General, 1958)

In 1958, Doll published the mortality experience of nickel workers and of several other occupations (14). Data for 15,247 men over the age of 15 years who were residents in the four selected districts of South Wales and who died in the period 1948-1956 were analyzed. Among coal miners, 73 deaths due to cancer of the lung were observed, while 152.16 deaths were expected from the experience of workers in all occupations. Thus, only 48% of the expected deaths were observed. Doll was aware of the possibility that the observed low incidence of lung cancer among the coal miners might have been a result of a relatively high mortality from other causes. According to the Registrar General, the death rates from all causes other than lung cancer among coal miners aged 20-64 years was 20% above the national average. Therefore, if the number of deaths from other causes among the coal miners was reduced by one sixth (20/120), the expected number of lung cancer deaths becomes 126.80, and, in this case, the observed number is 58% of the expected. This

attempt was the first quantitative effort to calculate a cause-specific SMR adjusted for deaths from other causes.

The population of the Rhondda Fach, a small mining valley in South Wales, was surveyed in 1950-51 (15). The community was re-surveyed in 1953, when 91% of the entire population and 95% of the miners and ex-miners were radiographed. The mortality experience of the population during 1950/51-1953 was reported by Carpenter et al in 1956 (16). With the entire population of England and Wales as control, standardized mortality ratios were calculated for the males and the females. It was noted that the age distributions in both sexes were very similar. Among the males aged 5 to 74, 342 deaths from all causes were observed, when 278.2 were expected, giving an SMR of 122.9. Among the females, 190 deaths were observed with 186.8 expected, giving an SMR of 101.7. It was suggested that the difference was due to some occupational factor. To pursue the problem further, the male population was divided into non-miners, miners and ex-miners with and without pneumoconiosis. The following results were obtained.

TABLE 1.5

SMR for Non-miners, Miners and Ex-miners
by category of CWP in the Rhondda Fach, South Wales, 1950/51-53

		Observed	Expected	SMR	SD
Non-Miners		28	26.9	104.1	19.67
Miners & Ex-miners	Category 0	115	104.4	110.2	10.27
	Categories 1, 2, 3 & A	82	73.9	111.0	12.25
	Categories B, C, D	47	33.9	138.6	20.22

(From Carpenter et al, 1956)

The authors suggested that there was no evidence that simple pneumoconiosis was associated with a decreased expectation of life, and that a trend of mortality apparently existed among the different categories of pneumoconiotics. The greatest excess of mortality was observed among miners and ex-miners with category B, C, or D Coal Workers' Pneumoconiosis (CWP).

Realizing the incomparability of SMR's when the age distributions and the population sizes were different, the authors proposed a transformed death rate

$$\Psi = \sqrt{n}\ (\sin^{-1}\sqrt{p} - \sin^{-1}\sqrt{q}),$$

where n = number of subjects,

p = observed percentage of deaths, and

q = expected percentage of deaths.

The value of Ψ is positive, zero or negative depending on whether there is excess, no excess or deficit of mortality, respectively. Each Ψ would have the same standard error of $\pm$ 28.7. Thus, an absolute value of Ψ greater than 57.4 would indicate a significant deviation from the expected mortality. Based on the values of Ψ's, it was concluded that there was no definite increasing trend of death rates among the radiological categories of CWP.

A six year (1951-1956) follow-up of the population in the Rhondda Fach was published in a later report in 1964 (17). The results suggested that Progressive Massive Fibrosis (PMF) was more serious than the previous study had implied. The SMR for miners and ex-miners aged 25-74 with PMF was 209.2, compared to the previous value of 138.6. The mortality of miners and ex-miners

without PMF was also significantly raised. The SMR for miners and ex-miners without pneumoconiosis was 126.8 and for those with categories 1, 2, 3 or A was 119.2. These two observations remained unchanged even after colliery accidents were excluded.

The major results of the six year follow-up of the Rhondda Fach miners are as follows:

(1) Those miners with progressive massive fibrosis had high standardized mortality ratios.

(2) There were no differences in the SMR's of those whose original x-ray category was 0 as compared to those with an x-ray category of 1, 2 or 3.

(3) The SMR of the non-miners was lower than those of miners and ex-miners with original x-ray categories 0, 1, 2, 3 combined.

All of these results were supported in the findings of the 20 year follow-up of this same group of men (18). Furthermore, it appears that on the basis of the 20 year follow-up that PMF category A does not lower the SMR but rather has the same life expectation as categories 0, 1, 2 and 3 (at least for the first 20 years).

Mortality from lung cancer among the residents in the Rhondda Fach was communicated to Goldman, who published the results as part of his 1965 review article on lung cancer among coal miners (19). Among the miners and ex-miners, 30 deaths were observed out of 37.0 expected, the corresponding SMR being 81.1. For the non-miners in the same community, only 3 out of the 5.7 expected deaths were observed, the SMR

being 53.1. The difference seemed to indicate that the miners and ex-miners were more vulnerable to lung cancer than the rest of the community. However, the statistical significance of the difference was limited because one of the SMR's was based on a very small number of deaths. This result also emphasized the importance of choosing an appropriate control group before inferences can be made.

Also reported in the same review article was the mortality of coal miners from lung cancer obtained from an investigation into the accuracy of the Registrar General's occupational data (20). Information was acquired through the National Coal Board and local inquiries about miners and ex-miners aged 20 to 65. The mortality experience of these men during 1955 is given in Table 1.6.

TABLE 1.6

Cancer SMR of Miners and Ex-miners
in England and Wales, 1955

	Underground Workers		Surface Workers	
	Lung Cancer	Other Cancers	Lung Cancer	Other Cancers
Deaths Observed	216	459	54	93
Deaths Expected	308	450	59	82
SMR	70.1	102.0	91.5	113.4

(From Goldman, 1965)

Both the undergound and surface workers had a lower incidence of lung cancer than the corresponding male population in England and Wales. Furthermore, the SMR for underground workers was considerably lower than that of surface workers. There were also considerable regional differences in lung cancer mortality. It was low in Durham (SMR = 63.2) and relatively high both in the south-west (SMR = 108.7) and in the north (SMR = 147.0). The relatively high rate in the south-west was in

conflict with the findings of Kennaway and Kennaway and of the Registrar General, but a close comparison was not possible, because of the differences between the regional divisions of the country and those of the National Coal Board.

In the same article, Goldman, based on the Registrar General's Quarterly Returns for Wales 1956-61, calculated the annual death rates from lung cancer in some selected mining and non-mining towns. To reduce the bias arising from differences in age and sex structures between the different populations, each crude death rate was multiplied by an appropriate "Area Comparability Factor". The adjusted death rates were seen to be lower in the towns situated in mining areas than those in non-mining areas. This low mortality from lung cancer in mining towns, the author concluded, would be in keeping with the low mortality recorded for miners.

From the Registrar General's data, Stocks derived the death rates from cancer of the stomach and from respiratory diseases among coal miners aged 20 to 65 in 1949-53 in the mining areas in England and Wales (21). The death rates of the non-miners in the same counties were also calculated. To insure a proper comparison, death rates were adjusted by the comparability factors based on age distribution and urbanization of residence. The mortality of the wives of the miners was also reported, but a further regional breakdown was not possible. For the calculation of standardized mortality ratios, the expected deaths were based on the entire population of England and Wales.

For cancer of the stomach, the SMR of all coal miners was 149, and the wives of coal miners showed a similar excess over all married women, their SMR being 154. In six out of the nine mining areas, the death rates from stomach cancer of the non-miners were considerably higher than the national average. In the remaining three areas, two showed no deviation and one less than the national average. Furthermore, in every area, the coal miners' rate exceeded both the national rate and that of non-miners. The excess varied from region to region, with the greatest difference occurring in an area in South Wales where 82% of the miners were working in anthracite mines at the time of the census.

For bronchitis among all miners in England and Wales, the SMR was 135, and among their wives, 175. In all areas considered, the miners showed a higher mortality from bronchitis than other male residents in the same community. Again, the greatest excess was observed in the same area in South Wales, where the excess in stomach cancer was the greatest. For respiratory tuberculosis, the SMR for all miners was 119 and for the wives, 145. However, the non-miners show a higher excess in mortality from respiratory tuberculosis than the miners in two areas.

The author suggested the following factors contributing to the observed regional differences: the coal itself or the manner of mining it, the rock and soil containing the coal, and the general environment of the communities. It was also concluded that since the miners'

population had been falling, some of the excess mortality among miners might have arisen from the transfer of healthy young men into other occupations.

There were three other conditions quoted by Stocks for which the Registrar General reported a standardized rate at ages 20-64 that was 15 percent or more in excess of that of all males taken as 100. These were pneumoconiosis (1277), chronic endocarditis not specified as rheumatic (146) and myocardial degeneration without mention of coronary or rheumatic disease (127). There was no regional investigation done for these causes of death.

An analysis of the mortality of British coal miners in 1961 was reported by Liddell (22). For all deaths registered in 1961 of men aged 20 to 64 in mining occupations or thought to have been employed by the National Coal Board, the Registrars General of England and Wales and of Scotland provided identity, age, occupation and cause of death. For each man on colliery books who died in 1961, collieries provided details including last occupation, place of death, and occupation in 1952 (or on first employment if later). Where it was not possible to match a death certificate with the information obtained from colliery, and in all cases where a man's last recorded employment was earlier than 1961, inquiries were made of the deceased's family through more than 200 medical offices and by mail.

The occupations as indicated on death certificates were considerably different from those determined by inquiry. Although 4212 death certificates were coded as coal miners, only 3131 were

definitely known to have had worked in the coal industry or 3555 if the 424 who had at least probably worked in the industry were included. Thus the "promotion", defined as the percent difference of the official figures, was, on the average, (4212 - 3555) / 4212 or 15.6%, ranging from 37.1% in Kent to 9.6% in Yorkshire. Promotion to the coal face was 46.7%; in other words, nearly half of the deaths coded as face workers on the death certificates were incorrectly coded as such. The following Table 1.7 shows the distribution of cause-specific deaths at ages 55 to 64, as compared to that of all occupied and retired males in England and Wales 1959-1963 at the same ages.

TABLE 1.7

Distribution of Deaths in Coal Mines Aged 55-64 in England and Wales, 1960.

Cause	Coal Miners (%)	All occupied and retired males, England and Wales 1959-1963
Coronary disease, angina	26.1	27.9
Vascular lesions of nervous system	7.8	8.4
Malignant neoplasm, lung bronchus	8.8	13.2
Bronchitis	12.0	9.3
Pneumoconiosis, occupational	4.6	0.4
All other causes	40.7	40.8
Number of deaths	3169 = 100%	273647 = 100%

(From Liddell, 1973)

There was a lower proportion due to malignant neoplasms of the lung and the bronchus than in the general population, but higher proportions due to bronchitis and to occupational pneumoconiosis.

A further analysis was carried out among the working miners. The denominators of death rates came from a 5% sample census of the mining industry in 1961. Cause-specific SMR's were calculated, using all occupied and retired males in England and Wales as the control. The results are presented in Table 1.8.

TABLE 1.8

Cause-specific SMR among Occupied Coal Miners in England & Wales, 1960

Cause	Face workers	Other underground workers	Surface workers
All causes	77	102	137
Coronary disease, angina	48	76	116
Vascular lesions of nervous system	49	63	94
Hypertension	40	83	99
Malignant neoplasms, lung, bronchus	49	53	82
Malignant neoplasms, stomach	101	128	32
Malignant neoplasms, other	69	72	101
Bronchitis	26	64	129
Pneumonia	25	58	132
Pneumoconiosis, occupational	191	413	556
Motor vehicle accident	73	113	149
Other accidents	357	236	221
Suicide	42	111	83
All other causes	39	63	106

(From Liddell, 1973)

It is interesting to note that the face workers had a deficit in mortality from every cause except occupational pneumoconiosis and other accidents, while the surface workers had excesses in most of the causes. Furthermore, there was an increasing trend of mortality across the categories of coal miners in every cause of death, except in stomach cancer

and in other accidents. This gradient was, as explained by the author, in accordance with the need for the fittest men at the coal face, the tendency for older men to move from the face when work became too arduous for them, and for surface workers to include the less fit. That the face workers had to be robust was indicated by their particularly low SMR's from pneumonia, bronchitis, hypertension, coronary disease, vascular lesions, and all other causes.

In conclusion, Liddell pointed out the fact that low mortality from cancer of the lung and bronchus was not balanced by neoplasms at other sites, and this appeared among both occupied and retired miners.

In the meantime there were no substantial investigations on the mortality of coal miners in the United States comparable to those done in Great Britain. Furthermore, as in Britain, the respiratory ailments of coal miners were first attributed to silica. This opinion was reinforced by studies done in the anthracite coal mines of Pennsylvania during the time period 1928-1931. The silica content in these mines was relatively high and the results of these studies indicated that the incidence of anthracosilicosis (a term used for the condition found in miner's lungs) was higher for those men exposed to dust with a higher percentage of silica.

Gradually, however, as a result of some of the reports of the British, supplemented by findings in the U.S. [Clarke and Moffet (23), Jones (24)] that indicated bituminous coal miners also had a high incidence of anthracosilicosis, the emphasis began shifting from silica as the sole cause.

Then in 1957 Levin and Hunter (25) reported pneumoconiosis, identical to the British counterpart, in a small group of Ohio coal miners. The U.S., although thirty years behind, was following the same course as the British.

In 1960, based on a review of death certificates, Vinyard and Lieben reported the pneumoconiosis mortality in Pennsylvania for the period March, 1957 to February, 1959 (26). Records of the National Office of Vital Statistics at that time revealed that more than 50% of the pneumoconiosis and about 93% of the anthracosilicosis deaths in the U.S. were reported from Pennsylvania. An extension of the study was reported by Lieben and Hill in 1962, covering the period between January, 1959 to December, 1960 (27).

This later study showed that for 1959-1960, more than one half (in 1957-1959, about two thirds) of the deaths with some mention of occupational lung disease on death certificates in Pennsylvania were mine workers. The high-risk age group was those more than 45 years old. Of the total deaths involving pneumoconiosis in the state, 82% occurred in 11 counties including 8 hard coal and 2 bituminous coal producing areas, and 76% of the total were concentrated in five counties (Luzerene, Schuylkill, Lackawanna, Carbon and Northumberland). In the Luzerene and Schuylkill counties, pneumoconiosis was the second most frequent cause of death among males over 45 years old, exceeded in frequency only by heart disease.

Of the 2772 male deaths reported in 1959-1960 with mention of occupational lung disease on the death certificate, 1739 (63%) stated that the occupational lung disease was the primary cause of death, while for the other 1033 deaths pneumoconiosis was specified to be an associated morbid condition existing at the time of death. For these 1033 deaths with pneumoconiosis as a contributory condition, heart disease was most frequently listed as the primary cause (49.1%), followed by malignant neoplasms (15.1%), and pneumonia and influenza (7.2%). The proportion dying from cancer in the pneumoconiosis group was slightly less than that in the state. However, a considerably higher percentage of those dying of cancer with occupational lung disease complications were specified to be due to cancer of the respiratory system.

In 1962, the U.S. Public Health Service published a study on general occupational mortality for the year 1950 (28). Mining was one of the occupations studied. A detailed mortality analysis by cause and by age based on the above study was reported by Enterline in 1964 (29). All deaths with coal miners listed as the usual occupation on the death certificates were included in the numerator. In order to compute the death rate, it was necessary to estimate the denominator, i.e., the number of men who, had they died in 1950, would have been classified as coal miners. Crude estimates were made from 1950 U.S. Census data for men in the labor force and from a special supplement to the February, 1954, Current Population Survey for former coal miners.

Death rates among coal miners were found to be considerably higher than those for all males with work experiences. At all ages 20-64 the

observed death rate was 95 percent (SMR = 195) above that for all male workers. Furthermore, the excess increased with age. At ages 20-64, SMR's were higher than the expected for every cause of death except diabetes (SMR = 100). The greatest excess came from accidents at work (SMR = 586), followed by diseases of the respiratory system (SMR = 491) and cancer of the stomach (SMR = 275). Other causes of death where the observed number was more than twice the expected included tuberculosis, cancer of the prostate, general arteriosclerosis, other myocardial degeneration, ulcer of the stomach and homicide, while lung cancer was almost twice as high (SMR = 192).

TABLE 1.9

Mortality of U.S. Coal Miners Aged 20-64, 1950

Cause	Observed	Expected	SMR
All Causes	5793	2966	195
Tuberculosis	396	148	268
Syphilis	55	30	183
Malignant neoplasms	764	428	179
Stomach	146	53	275
Trachea, bronchus, lung	161	84	192
Prostate	35	17	206
Diabetes	33	33	100
Strokes	309	193	161
CHD	1140	789	144
Disease of respiratory system	487	99	491
Occupational pneumoconiosis	321	--	--
Accident	967	338	286
At home	499	80	586
Homicide	119	51	233

(From Enterline, 1964)

Enterline commented that, although the high rates in some of the diseases such as "other myocardial degeneration" and "general arteriosclerosis" might be artifacts due to diagnostic standards and

nomenclature used in coal mining communities, the high rates in accidents at work and in respiratory disease were clearly related to coal mining. The relationship of other diseases to coal mining was less certain. It was argued that if the environment in which coal miners lived was a causal factor in their high mortality rates, then it would be expected that they would be increasingly unhealthy, relative to other workers, as they grew older. Essentially the author used age as a substitute for length of employment, which would be valid if all coal miners started at approximately the same age. Such a trend of increasing mortality was observed in disease of the respiratory system, tuberculosis and cancer of the trachea, the bronchus and the lung, while no definite pattern was found in cancer of the stomach, in other myocardial degeneration, in accidents at work and in CHD. It was concluded that some of the excesses were no doubt due to diseases and conditions associated with the working environment and dust inhalation, while others could be a reflection of the socio-economic environment of coal mining communities. The possibility of a selective out-migration of healthier workers was also discussed.

In addition to the above study, Enterline (30) wrote a review paper in which he included some findings on mortality in the coal mining industry based on some data from the Society of Actuaries. Two earlier Actuarial studies on the mortality of policy holders in the underground coal mining industry covering the periods 1915-1926 and 1927-1935 indicated that the observed deaths were above two and a half times higher than the expected based on policies issued under standard risks. A third report covering 1949-1963 indicated a somewhat smaller excess, the all-cause

SMR being 172. The excess was chiefly due to respiratory disease and tuberculosis (SMR = 1111), accidents and homicide (SMR = 626) and digestive disease (SMR = 260). One interesting point was that there was a slight deficit of mortality in malignant neoplasms, with SMR = 80.

Also included in the above review article was a 28-1/2 year follow-up study of a group of 533 men aged 22-32 in 1937 working in three coal mines in the Beckley area. Among them, 140 deaths were observed, compared to an expected number of 88.7, giving an SMR of 157.9. The SMR's in tuberculosis, syphilis, digestive cancer, respiratory cancer, disease of the respiratory system and accidents were 173.9, 445.9, 210.0, 110.9, 150.0 and 269.6, respectively. However, since the number of observed deaths were quite small, the cause-specific ratios must be interpreted with caution.

The mortality experience of Pennsylvania coal miners compensated for disability due to CWP was analyzed by Ortmeyer, Baier and Crawford (31). Between December 1, 1965 and December 31, 1967, 22,400 coal miners, who had worked for at least 2 years in Pennsylvania coal mines, applied for benefits under the 1965 Pennsylvania Occupational Disease Act. Chest roentgenograms given to each applicant were categorized for CWP according to the 1957 ILO classification. Included in the study were 607 men with stage C complicated CWP. Applicants with categories 2 and 3 (simple) CWP or stages A and B (complicated) CWP were further divided into two groups according to spirometric examination: those with FEV/FVC less than or equal to 55% and those greater than 55%. All the 1165 in the first group were included, while only 449 (20% sample) of

the second group were included. Only 20% or 1783 of those with category 1 CWP were admitted to the study. Thus, the total number was 4004, 2958 being anthracite miners and 1046 bituminous miners. The mortality experience of the entire group was followed up to January 1, 1971.

Standardized mortality ratios from all causes, based on the deaths expected of white males in Pennsylvania in 1959-1961, were calculated for these 4004 miners. The results are summarized in Table 1.10.

TABLE 1.10

Mortality of Coal Miners by Categories and Stage of CWP in Pennsylvania, 1965/67-1970

Deaths by Area		Total Deaths	Simple CWP		Complicated CWP			
			1	2 & 3	A with 1	A with 2 & 3	B	C
Both Areas	Obs.	1455	84	511	35	187	311	327
	Exp.	1188	88	432	35	160	223	180
	SMR*	119	96	113	100	112	138	182
Anthracite	Obs.	1119	51	394	15	140	250	269
	Exp.	810	47	318	13	117	175	140
	SMR*	127	108	118	119	115	143	192
Bituminous	Obs.	336	33	117	20	47	61	58
	Exp.	306	40	113	22	44	47	40
	SMR*	100	82	99	90	105	120	145

* SMR computed from weighted estimates since it was based on both 20% and 100% samples.

(From Ortmeyer et al, 1973)

There was a significant excess of deaths in the population as a whole (SMR = 119). For both anthracite and bituminous miners, the greatest excess of deaths came from miners with stage C complicated CWP, followed by those with stage B. Among the anthracite miners, mortality was elevated 15% to 20% in those with categories 2 and 3 simple CWP and stage A complicated CWP, while there was no significant excess in the corresponding groups among the bituminous miners.

When mortality was analyzed according to lung function results, the excess mortality in miners with stages A and B could be completely explained by those with reduced ventilatory capacity. Mortality for men at the working ages (under 65) was considerably higher than that for men aged 65 and over, regardless of category or stage of CWP or level of ventilation capacity.

In 1962-1963, 4134 Appalachian miners were randomly selected by the U.S. Public Health Service for a prevalence study of CWP (32). Of the sample, 3726 (90%) coal miners agreed to participate. The cohort was followed up to January 1, 1972, and then mortality experience was reported by Costello, Ortmeyer and Morgan (33).

Of the original cohort, 451 men were certified as having died during this period, and the vital status of about 230 (6%) men remained undetermined. Expected deaths were calculated from the rates for all males in the United States in 1968. A total of 30 deaths were attributed to cancers; 24 to lung cancer, 2 to esophagus cancer, 1 to nasopharynx cancer and 3 to stomach cancer. The SMR for lung cancer was 67, based on 36 expected deaths. When lung cancer deaths were analyzed by age, it was discovered that the age group 65-69 was most vulnerable, with 9 observed deaths while only 1 was expected. It was pointed out that 21 of the 24 miners dying from lung cancer either were or had been cigarette smokers, and one was a pipe smoker.

In conclusion, the authors pointed out the disagreement on lung cancer mortality among coal miners between the British studies and the

previous American studies. Based on this study, the authors concluded that the experience of the Appalachian miners tended to confirm the British findings in regard to the lower than normal mortality from lung cancer in coal miners.

The mortality of the same cohort by categories of CWP, by duration of underground mining, by smoking history, by lung function test and by respiratory impairment symptoms was reported in a later article (34). The original cohort of 3726 was divided into 2549 employed miners and 1177 ex-miners. The vital status as of January 1, 1972 was determined for 95% of the employed miners and 99% of the ex-miners. Standardized mortality ratios were computed using the entire population of the U.S. as the basis for comparison.

Among the actively employed miners, only 225 deaths out of the 241.9 expected were observed (SMR = 93), whereas 308 deaths took place among the ex-miners when only 248.5 were anticipated (SMR = 124). The combined weighted SMR for the entire cohort was 104. When the miners were analyzed by their radiographic categories of CWP, and by their duration underground, the following results were obtained (Table 1.11).

TABLE 1.11

Mortality of Appalachian Coal Miners by Category of CWP and Duration Underground, 1963-1971

	Years Underground	Category 0		Simple CWP		Complicated CWP	
		Deaths	SMR	Deaths	SMR	Deaths	SMR
Employed Miners	≤ 29	110	91	5	61	2	90
	30+	76	93	15	87	13	143
Ex-Miners	≤ 29	86	120	6	87	14	221
	30+	149	119	28	143	25	138

(From Ortmeyer et al, 1974)

For the miners and ex-miners without radiographic evidence of CWP, the SMR's were about the same, whether they had been underground for more or less than 30 years. For those with simple CWP, only those ex-miners with more than 30 years experience of underground mining showed an elevated mortality. Employed miners afflicted with complicated CWP who had less than 30 years of underground mining had a much lower mortality than their counterpart in the ex-miners. Finally, miners with both complicated CWP and more than 30 years of underground mining exhibited a significantly increased mortality, whether employed or not.

It was found that cigarette smoking had a greater impact on death rates than the duration underground. Table 1.12 shows that even within the high-risk ex-miners, neither the non-smokers nor the ex-smokers showed any elevated death rate, except for men with complicated CWP. On the other hand, smokers in every category of CWP, whether employed or not, showed a significantly higher mortality . The greatest excess mortality was observed in smokers with complicated CWP.

TABLE 1.12

Mortality of Appalachian Coal Miners by Category of CWP and by Cigarette Smoking, 1963-1971

	Smoking habit	Category 0		Simple CWP		Complicated CWP	
		Deaths	SMR	Deaths	SMR	Deaths	SMR
Employed Miners	Never smoked	31	72	2	39	0	--
	Smoked in past	23	55	3	41	4	125
	Smoked when examined	130	111	15	115	11	244
Ex-miners	Never smoked	37	73	7	95	7	125
	Smoked in past	60	103	7	115	14	138
	Smoked when examined	136	158	19	148	16	198

(From Ortmeyer et al, 1974)

The best predictor of excess mortality in both employed and ex-miners was airway obstruction (Table 1.13). Airway obstruction was defined by the ratio of the volume of gas exhaled in the first second of a forced exhalation to the total volume exhaled, i.e., FEV./FVC, being less than 70%. No miners, regardless of their employment or CWP status, showed any excess mortality, provided their FEV./FVC ratio was at least 70%.

TABLE 1.13

Mortality of Appalachian Miners by Category of CWP and by FEV./FVC Ratio, 1963-1971

	FEV./FVC Ratio	Category 0		Simple CWP		Complicated CWP	
		Deaths	SMR	Deaths	SMR	Deaths	SMR
Employed Miners	<70%	76	115	7	69	11	192
	≥70%	105	82	12	85	4	86
Ex-miners	<70%	120	134	17	140	23	168
	≥70%	83	103	11	93	7	98

(From Ortmeyer et al, 1974)

Some correlation was found between the severity of dyspnea and the increased mortality in miners without CWP and in some with simple CWP. However, no such correlation was found for those with complicated CWP. The presence of chronic bronchitis symptoms (cough with sputum) was associated with elevated death rates in all three groups of employed miners and in the ex-miners without CWP. However, the ex-miners with complicated CWP but no chronic bronchitis symptoms (SMR = 177) showed a considerably higher mortality than the corresponding ex-miners with such symptoms.

Ortmeyer et al also discussed the possible sources of disagreement between their study and the one reported for all U.S. coal miners in 1950. The most probable origins of the difference were: (1) misclassification of coal miners and ex-miners in the 1950 deaths and populations; (2) exceedingly high death rates among the 136 (6%) employed miners lost to follow-up in their study; (3) a faster downward trend in death rates for coal miners than that for all U.S. males from 1950 to the period 1963-1971. Among these three possibilities, the second one seems highly hypothetical. It should also be noted that their study consisted of bituminous coal miners only, whereas the 1950 study consisted of both bituminous and anthracite coal miners.

While most effort has been concentrated on respiratory diseases among the coal miners, other diseases have also been observed to be high in this occupation. Matalo et al (35) noted the earlier results of Dixon that indicate a high incidence of gastric carcinoma in Carbon County, Utah. Motivated by these results, Matalo and his colleagues studied the incidence of stomach cancer in Carbon and Emery Counties, the only coal mining regions in the state of Utah. An adjacent non-coal mining area, Utah County, was chosen as a control.

The variables taken into account were sex, age, ethnic group, nativity, occupation, diet, house-heating system, blood type, family history of cancer, and socio-economic class. The study included those patients who were recorded to have stomach cancer in the Rocky Mountain States

Cooperative Tumor Registry. The SMR's for males was 342 in Carbon County and 338 in Emery County when compared to the entire state of Utah. The SMR for Utah County when compared to the entire state was 77. Although the SMR was also high in stomach cancer for females in the coal mining regions (152 and 229 respectively) it was more pronounced for males. The author notes that all the houses in Carbon and Emery County were heated by coal as opposed to natural gas or electricity used in Utah County. The diet and socio-economic class distributions are stated to be similar in the three counties, and although in Carbon County a high percentage of the patients were foreign born, in Emery County the patients were mostly local residents. The authors conclude that the high incidence of gastric cancer in Carbon and Emery Counties "could be related to frequent exposure to coal carrying carcinogenic hydrocarbons, in addition to the other unknown etiologic factors."

The results of Matalo et al in Utah prompted Creagan, Hoover and Fraumeni (36) to do the same type of analysis for a larger group. The mortality from gastric cancer among the white population in 23 coal mining counties in seven states in the United States during 1950 to 1969 was compared with the rates of other counties in the corresponding states that were matched by educational level.

The number of fatalities was ascertained from the National Center for Health Statistics. Population estimates for counties were calculated by linear interpolation of census data for 1950, 1960 and 1970. SMR's were calculated for all the coal mining areas for both sexes. Among the

males, there were 969 deaths attributed to stomach cancer compared to 721.6 death expected from rates in control counties (Risk Ratio = 1.3, $P < 0.001$). Among the females, 513 deaths were observed with 446.9 anticipated (Risk Ratio = 1.2, $P < 0.001$). The excess mortality in coal mining counties was slightly greater for men than women in all states except Illinois and Ohio.

Among the males in coal mining areas, excess deaths were observed in lung cancer (Risk Ratio = 1.3, $P < 0.001$), but mortality was significantly low from leukemia (Risk Ratio = 0.9, $P < 0.05$), and from colon cancer (Risk Ratio = 0.8, $P < 0.001$). The females had increased deaths from cervix cancer (Risk Ratio = 1.2, $P < 0.001$) and from lung cancer (Risk Ratio = 1.1, $P < 0.05$), while mortality from breast cancer (Risk Ratio = 0.9, $P < 0.001$) and from colon cancer (Risk Ratio = 0.8, $P < 0.001$) were less than the expected. Thus, there was an excess in cancers associated with low socio-economic class, and a deficit in cancers related to high socio-economic class. It was suggested that the mortality experience reflected the socio-economic class status rather than the occupation.

Several other types of cancers have been mentioned as possibly being related to coal miners, but data sources are small and the findings are only suggestive. Creagan and Fraumeni (37) suspect that the high incidence of brain tumors in Eastern Kentucky for the time period 1963-1969 may be related to occupation. Most of the men in this area are engaged in either coal mining or farming. In another study, Wynder et al (38) suggest a possible association between bladder cancers and coal mining. However, the numbers were too small for any strong statement.

In regard to cardiovascular disease among coal miners the results of a recent study by Costello, Ortmeyer and Morgan is of interest (39). Using the same cohort of 3726 Appalachian coal miners which was discussed earlier, they computed an SMR for working and nonworking miners for all heart disease and for the subcategory of ischemic heart disease. Comparisons were made with both the standard U.S. male population and the male population of the seven Appalachian states. The results are presented in Table 1.14.

TABLE 1.14

Mortality of Appalachian Coal Miners
for Heart Disease and Ischemic Heart Disease

	Obs.	U.S. Exp.	7 States Exp.	U.S. SMR	7 States SMR
Working Miners					
All Heart Disease	76	104	108	73	70
Ischemic Heart Disease	69	95	100	73	69
All Causes	200	242	249	83	80
Nonworking Miners					
All Heart Disease	122	117	122	104	100
Ischemic Heart Disease	114	109	112	105	102
All Causes	272	249	269	109	101

No excess of cardiovascular disease is indicated in their findings. When SMR's were computed on the basis of weight and smoking status, both normal weight and obese smokers in the nonworking cohort had excess mortality, while only obese smokers in the working group had excess mortality.

The literature in regard to the mortality and morbidity of coal mining is very extensive and a comprehensive review of all of it would be

a large undertaking. The main purpose of this review was to provide some historical perspective in regard to the health problems associated with coal mining, while at the same time selecting those papers which deal more directly with the types of problems this study may help answer. Thus, we have discussed only the British and U.S. findings, have emphasized mortality studies rather than morbidity studies, and have not discussed in as great a detail as might be considered merited those studies which have taken into account variables (smoking, diet, etc.) which our study has not considered. A brief summary of the studies we have presented and their results are presented chronologically in Table 1.15.

TABLE 1.15
Summary of Previous Studies

STUDY	METHOD	TIME	STUDY GROUP	CONTROL GROUP	MAJOR FINDINGS
KENNAWAY & KENNAWAY (1936)	DEATH CERTIFICATES AND CENSUS	1921–1932	COAL MINERS IN ENGLAND AND WALES	GENERAL POPULATION IN ENGLAND AND WALES	LUNG CANCER SMR = $\frac{289}{492.5} \times 100 = 59$; LARYNX CANCER SMR = $\frac{257}{484.1} \times 100 = 53$
KENNAWAY & KENNAWAY (1947)	DEATH CERTIFICATES AND CENSUS	1933–1938	COAL MINERS IN ENGLAND AND WALES	GENERAL POPULATION IN ENGLAND AND WALES	LUNG CANCER SMR = $\frac{485}{820.2} \times 100 = 59$; LARYNX CANCER SMR = $\frac{182}{277.6} \times 100 = 66$
JAMES (1955)	EXAMINATION OF THE NECROPSIES OF MINERS WITH PNEUMOCONIOSIS AND OF NON-MINERS	1947–1952	1827 MINERS WITH PNEUMOCONIOSIS AND 1531 NON-MINERS IN SOUTH WALES	RELATIVE RISK BASED ON THE RATE FOR ALL MINERS	MINERS WITH SIMPLE PNEUMOCONIOSIS: SLIGHT: LUNG CANCER RR = $\frac{31}{17.5} \times 100 = 177$ MODERATE: LUNG CANCER RR = $\frac{11}{9.1} \times 100 = 121$ SEVERE: LUNG CANCER RR = $\frac{7}{5.7} \times 100 = 122$ MASSIVE FIBROSIS LUNG CANCER RR = $\frac{12}{28.7} \times 100 = 42$ NON-MINERS LUNG CANCER RR = $\frac{82}{51} \times 100 = 161$ THE REMARKABLY LOW MORTALITY FROM LUNG CANCER AMONG MINERS WITH PMF SUGGESTS COMPETING RISK.
DOLL (1958)	DEATH CERTIFICATES	1948–1956	COAL MINERS IN SOUTH WALES	ALL WORKERS IN SOUTH WALES	LUNG CANCER SMR = $\frac{73}{152.2} \times 100 = 48$
CARPENTER ET AL (1956)	CROSS-SECTIONAL STUDY	1950–1953	RESIDENTS OF THE RHONDDA FACH, SOUTH WALES	GENERAL POPULATION OF ENGLAND AND WALES	MINERS AND EX-MINERS CATEGORY 0: SMR = $\frac{115}{104.4} \times 100 = 110.2$ CATEGORY 1,2,3,A: SMR = $\frac{82}{73.9} \times 100 = 111.0$ CATEGORY B,C,D: SMR = $\frac{47}{33.9} \times 100 = 138.6$ NON-MINERS SMR = $\frac{28}{26.9} \times 100 = 104.1$
COCHRANE ET AL (1964)	6-YEAR FOLLOW-UP COHORT STUDY	1951–1956	RESIDENTS OF THE RHONDDA FACH, SOUTH WALES	GENERAL POPULATION OF ENGLAND AND WALES	MINERS AND EX-MINERS CATEGORY 0: SMR = $\frac{331}{260.9} \times 100 = 126.8$ CATEGORY 1,2,3,A: SMR = $\frac{228}{191.3} \times 100 = 119.2$ CATEGORY B,C,D: SMR = $\frac{166}{79.4} \times 100 = 209.2$
GOLDMAN (1965)	6-YEAR FOLLOW-UP COHORT STUDY	1951–1956	RESIDENTS OF THE RHONDDA FACH, SOUTH WALES	GENERAL POPULATION OF ENGLAND AND WALES	MINERS AND EX-MINERS LUNG CANCER SMR = $\frac{90}{97} \times 100 = 81.1$ NON-MINERS LUNG CANCER SMR = $\frac{3}{5.7} \times 100 = 53.1$

TABLE 1.15 (Cont'd.)
Summary of Previous Studies

STUDY	METHOD	TIME	STUDY GROUP	CONTROL GROUP	MAJOR FINDINGS
HEADMAN ET AL (1958) GOLDMAN (1965)	DEATH CERTIFICATES AND INFORMATION FROM THE NATIONAL COAL BOARD	1955	COAL MINERS OF ENGLAND AND WALES	GENERAL POPULATION OF ENGLAND AND WALES	UNDERGROUND WORKERS LUNG CANCER SMR = $\frac{216}{308} \times 100 = 70.1$ OTHER CANCER SMR = $\frac{459}{450} \times 100 = 102.0$ SURFACE WORKERS LUNG CANCER SMR = $\frac{54}{59} \times 100 = 91.5$ OTHER CANCER SMR = $\frac{93}{82} \times 100 = 113.4$
STOCKS (1962)	DEATH CERTIFICATES AND CENSUS	1949 - 1953	COAL MINERS AND THEIR WIVES IN ENGLAND AND WALES	GENERAL POPULATION OF ENGLAND AND WALES	COAL MINERS STOMACH CANCER SMR = 149 BRONCHITIS SMR = 135 RESP. TB SMR = 119 THEIR WIVES STOMACH CANCER SMR = 154 BRONCHITIS SMR = 175 RESP. TB SMR = 145
VINYARD & LIEBEN (1960) LIEBEN & HILL (1962)	DEATH CERTIFICATES	1957-59 1959-62	DEATHS WITH MENTION OF PNEUMOCONIOSIS IN PENNSYLVANIA		PNEUMOCONIOSIS AS PRIMARY CAUSE OF DEATH : 63% PNEUMOCONIOSIS AS CONTRIBUTORY CAUSE OF DEATH : 37% AMONG THESE, 49.1% WITH HEART DISEASE AS PRIMARY CAUSE 15.1% WITH CANCER AS PRIMARY CAUSE 7.2% WITH PNEUMONIA AND INFLUENZA AS PRIMARY CAUSE
ENTERLINE (1964) PHS (1962)	DEATH CERTIFICATES AND CENSUS	1950	COAL MINERS IN US	MALES WITH WORKING EXPERIENCE IN US	OVERALL SMR = $\frac{5793}{2966} \times 100 = 195$ TB SMR = $\frac{396}{198} \times 100 = 268$ LUNG CANCER SMR = $\frac{161}{84} \times 100 = 192$ STOMACH CANCER SMR = $\frac{146}{53} \times 100 = 275$ CHD SMR = $\frac{1140}{799} \times 100 = 144$ RESP. DISEASE SMR = $\frac{487}{99} \times 100 = 491$ ACCIDENT SMR = $\frac{967}{338} \times 100 = 286$ MORTALITY WAS HIGH IN ALMOST ALL MAJOR CONDITIONS. A POSITIVE CORRELATION BETWEEN MORTALITY AND AGE WAS FOUND IN RESPIRATORY DISEASE, TB AND LUNG CANCER.
ENTERLINE (1972)	DATA FROM THE SOCIETY OF ACUTARIES	1949-1963	POLICY HOLDERS IN UNDERGROUND MINING	POLICY HOLDERS UNDER STANDARD RISK	OVERALL SMR = 172 RESPIRATORY DIS. SMR = 1111 ACCIDENT SMR = 626 DIGESTIVE DIS. SMR = 260 CANCER SMR = 80
ENTERLINE (1972)	28½ YEAR FOLLOW-UP COHORT STUDY	1937-1966	533 MEN WORKING IN COAL MINES IN BECKLEY AREA IN 1937	US MALE POPULATION	OVERALL SMR = $\frac{140}{88.7} \times 100 = 157.9$ TB SMR = $\frac{8}{4.6} \times 100 = 173.9$ SYPHILIS SMR = $\frac{4}{.9} \times 100 = 445.9$ DIGESTIVE CANCER SMR = $\frac{8}{3.8} \times 100 = 210.0$ LUNG CANCER SMR = $\frac{4}{3.6} \times 100 = 110.$ RESP. DIS. SMR = $\frac{6}{4} \times 100 = 150$ ACCIDENT SMR = $\frac{31}{115} \times 100 = 369.$

TABLE 1.15 (Cont'd.)
Summary of Previous Studies

STUDY	METHOD	TIME	STUDY GROUP	CONTROL GROUP	MAJOR FINDINGS
LIDDELL (1972)	DEATH CERTIFICATES + INFORMATION FROM THE NATIONAL COAL BOARD AND A 5%-SAMPLE CENSUS OF MINING INDUSTRY IN 1961	1960	COAL MINERS IN ENGLAND AND WALES	OCCUPIED AND RETIRED MALES IN ENGLAND AND WALES 1959-1963	FACE WORKERS / OTHER UNDERGROUND WORKERS / SURFACE WORKERS OVERALL SMR: 77 / 102 / 137 LUNG CANCER SMR: 49 / 53 / 82 STOMACH CANCER SMR: 101 / 128 / 32 BRONCHITIS SMR: 26 / 64 / 129 PNEUMONIA SMR: 25 / 58 / 132 PNEUMOCONIOSIS SMR: 191 / 413 / 556 ACCIDENT (EXCL. VEHICLE) SMR: 357 / 256 / 221
ORTMEYER ET AL (1975)	A FIVE YEAR FOLLOW-UP COHORT STUDY	1965/67-1970	PENN. COAL MINERS COMPENSATED FOR CWP DURING DEC 1965 - DEC. 1967	WHITE MALES IN PENN. 1959-61	ANTHRACITE (N=2958) / BITUMINOUS (N=1046) SIMPLE AND STAGE A CWP: SMR: 108 - 119 / SMR: 82 - 105 STAGES B AND C CWP: SMR: 143 - 192 / SMR: 120 - 145
CREGAN ET AL (1974)	DEATHS OBTAINED FROM NATIONAL CENTER FOR HEALTH STATISTICS. POPULATION ESTIMATED FROM CENSUS.	1950-1969	RESIDENTS IN 23 COAL MINING COUNTIES IN US	RESIDENTS IN NON-COAL MINING COUNTIES IN THE SAME STATES AND MATCHED BY EDUCATION LEVEL.	MALES / FEMALES STOMACH CANCER RISK RATIO: 1·3 / 1·2 LUNG CANCER RISK RATIO: 1·3 / 1·1 LEUKEMIA RISK RATIO: 0·9 / 1·1 COLON CANCER RISK RATIO: 0·8 / 0·8 BREAST CANCER RISK RATIO: — / 0·9 CERVIX CANCER RISK RATIO: — / 1·2
COSTELLO ET AL (1974)	10 YEAR FOLLOW-UP COHORT STUDY	1962/63-1971	3726 APPALACHIAN COAL MINERS (THE 1950 PHS CWP STUDY)	MALE POPULATION IN US 1968	LUNG CANCER SMR = $\frac{24}{36} \times 100 = 67$ 22 OUT OF THE 24 LUNG CANCER DEATHS WERE OR HAD BEEN SMOKERS
ORTMEYER ET AL (1974)	10 YEAR FOLLOW-UP COHORT STUDY	1962/63-1971	3726 APPALACHIAN COAL MINERS (THE 1950 PHS CWP STUDY)	MALE POPULATION IN US 1968	OVERALL SMR = 104 CATEGORY 0: DEATHS / SMR; SIMPLE CWP: DEATHS / SMR; COMPLICATED CWP: DEATHS / SMR EMPLOYED MINERS — NON-SMOKERS: 91 / 72 / 2 / 59 / 0 / – EMPLOYED MINERS — EX-SMOKERS: 23 / 55 / 3 / 41 / 4 / 125 EMPLOYED MINERS — SMOKERS: 130 / 111 / 15 / 115 / 11 / 244 EX-MINERS — NON-SMOKERS: 37 / 73 / 7 / 95 / 7 / 125 EX-MINERS — EX-SMOKERS: 60 / 103 / 7 / 115 / 14 / 138 EX-MINERS — SMOKERS: 136 / 158 / 19 / 148 / 16 / 198 EMPLOYED MINERS — $FEV_1/FVC < 70\%$: 76 / 115 / 7 / 69 / 11 / 192 EMPLOYED MINERS — $FEV_1/FVC \geq 70\%$: 105 / 82 / 12 / 85 / 4 / 86 EX-MINERS — $FEV_1/FVC < 70\%$: 120 / 134 / 17 / 140 / 23 / 168 EX-MINERS — $FEV_1/FVC \geq 70\%$: 83 / 103 / 11 / 93 / 7 / 98
COSTELLO ET AL (1975)	10 YEAR FOLLOW-UP COHORT STUDY	1962/63-1971	3726 APPALACHIAN COAL MINERS (THE 1950 PHS CWP STUDY)	MALE POPULATION IN US 1968 MALE POPULATION IN APPALACHIA 1968	WORKING MINERS ALL HEART DISEASE SMR = $\frac{76}{104} \times 100 = 73$ (US) ISCHEMIC HEART DISEASE SMR = $\frac{69}{\ldots} \times 100 = 73$ NONWORKING MINERS ALL HEART DISEASE SMR = $\frac{122}{117} \times 100 = 104$ (US) ISCHEMIC HEART DISEASE SMR = $\frac{114}{\ldots} \times 100 = 105$

II. Scope of Present Study

The main purpose of this study is to determine whether or not coal miners have an excess mortality when compared to the total U.S. population. In regard to the mortality experience of the U.S. coal miner, the previous studies have been so contradictory that even when essentially the same control populations have been used the results have differed dramatically. Thus it becomes important to resolve whether or not coal miners as a group have a high mortality when compared to the total U.S. population as indicated in (29, 30), or whether their experience is more comparable to British coal miners as indicated in (33, 34, 39).

Secondly, it is of interest to determine which causes of death, if any, are associated with coal mining. Of special interest are stomach cancer, lung cancer, and nonmalignant respiratory diseases since these have been the most frequently mentioned in the literature. There appears to be agreement on the high rate of stomach cancer although its exact relationship to coal mining is obscure. The lung cancer rates among coal miners are conflicting, and although there is general agreement that nonmalignant respiratory diseases are high, there is no general agreement as to which subcategories are elevated.

Although it would also be interesting to study mortality in regard to length of exposure, amount of exposure, mining technique used and type of coal mined, this is, unfortunately, beyond the scope of this study. Partial work histories are available only for those miners who were pensioned and

even in these cases some are incomplete since it was only necessary to show sufficient work experience to be eligible for pension. Exposure levels can of course only be crudely estimated for that time period. Even the mining techniques change over time and a worker would probably be exposed to several different techniques. Furthermore, the fact that the same technique produces such a large variation in dust levels at different mines (40) may indicate that any relationship, even if it existed, might be difficult to recognize. Some indication might be obtained in regard to the type of coal mined, although for the Appalachian region the rank of coal varies to such an extent that it might be necessary to undertake the difficult task of identifying the mine in which a miner was employed. The problem also exists that if the miner were mobile he may have mined coal of varying ranks.

III. Materials and Methods

A. Definition of the Cohort and Data Processing

The United Mine Workers of America Health and Retirement Funds (the Fund) at the time of data collection had records for approximately 550,000 men who at one time had been eligible for medical benefits. Of these, 190,000 were kept separately and we will hereafter refer to them as the Active File. This represented men who at the present time were eligible for medical benefits. A man remains eligible for benefits as long as he meets one of the following three conditions:

(1) he is a working miner in a signatory company*

(2) he is pensioned

(3) he is unemployed but he has worked for a signatory company within the last year**

The remaining 360,000 records were for miners who were no longer eligible for benefits (Inactive File). Since many of the men in this file may again become eligible, there is a certain amount of transferring that takes place between the two files. However, in order to create filing space the Fund has in some cases destroyed records of men whom they feel have no possibility of again becoming eligible for benefits. The last time this occurred for this file was in 1958. Therefore, the date which was chosen to define the cohort was January 1, 1959.

* There is a minimum requirement as regards number of hours and there are certain jobs which do not qualify the miner for eligibility.

** If a miner is eligible for Workmen's Compensation, he may be carried for up to 4 years.

The Fund record contained name, social security number, district number, local union number, birthdate, age, and last known address. The first date that a man entered the Fund was also indicated. However, since for 72.6% of the cohort this date corresponded to the earliest date listed on Fund records (July 1, 1950) and, of course, in no case was the date later than January 1, 1959, it was not adequate for estimating length of exposure. If a miner was no longer covered by the Fund, there was a "VOID" stamped on the record with the date he became inactive and the reason. If a man had been pensioned, the record was stamped to indicate this but, in general, there was no pension date. If the Fund had knowledge of the miner's death the record was stamped "DECEASED" with a date of death. On most records, but not on all of them, the dependents of the miner were also listed, and in some cases these were useful in the later stages of follow-up. The periods of inactivity after the miner joined the Fund were indicated in various places on the back of the record and this information was necessary in order to determine which men were active on January 1, 1959.

A 10% sample was taken of the 550,000 records by taking a random start for each file cabinet drawer and selecting every tenth record. After a record was selected an examination was made to determine if the miner was eligible for Fund benefits January 1, 1959. If the miner was eligible, the record was microfilmed. The final number of 23,253 thus represents a 10% sample of miners eligible for benefits January 1, 1959. Twenty of these were subsequently eliminated from the cohort. One miner was excluded because the birthdate was omitted from his

record. The remaining nineteen died prior to January 1, 1959 but were still considered eligible on that date per way of Fund records.

After workable copies of the records were obtained, coding jackets or envelopes were prepared and the reproductions were inserted for later coding. All information subsequently obtained for each miner was kept in this folder, which was constructed so that all coding could be done directly onto the front of the envelope. All coding was verified independently by a second clerical person. Cards were keypunched directly from the front of the envelopes and all work was verified independently by a second keypunch operator. After reading the cards onto tape, a program was written to edit the data and any discrepancies were resolved. Corrections were made on both the tape and the cards in order that a "back-up" file be maintained.

B. Follow-Up

An essential part of this or any other mortality study is the ability to make a vital status determination of all cohort members during the period of observation. In the case of the Miner's Health and Retirement Fundscohort this determining date was December 31, 1971. Figure 1 presents a summary of the results of the various follow-up procedures.

The 9100 men in the Active File were assumed to be alive at the end of the follow-up period and no further follow-up was initiated. The remainder were submitted to the central data processing office of the Internal Revenue Service. After submitting a deck of punch cards showing name, social security number, and other identifying information, we were sent the date the last income tax return was filed. Of the group submitted to IRS we identified 3588 of the miners as alive at the end of the study period. A miner was considered alive December 31, 1971 per way of IRS return if both of the following conditions were satisfied:

(1) An income tax return was filed in 1973. (for the earnings in 1972)

(2) The miner himself signed the return and there was no indication of a death.

Thus, even if a return was filed in 1973 the miner was not assumed to be alive if only his wife's signature was present or if there was any indication of a death. In these cases an attempt was made to obtain a death certificate to verify exact date of death.

In the meantime, while awaiting the information from IRS, a search was made at the Fund for the death certificates of the miners whose Fund record indicated a death. Since the Fund paid a death benefit for which certification of death was required, many of these certificates were available. Approximately 3500 acceptable death certificates were obtained at the Fund. An additional 2500 certifications of death were obtained but they were not an original state copy and provided only a summary (underlying cause and date of death) of the information recorded on the state certificate. However, provided with the date of death and the state in which the certificate was filed, the original certificate was readily obtained. Approximately 780 additional miners were indicated dead on the Fund record but no certificate was on file at the Fund. Most of these certificates were subsequently obtained by sending requests to the state of last residence and in some cases by supplementing this information with "post office follow-up". In summary, state certificates were obtained for 6745 of the coal miners identified by the Fund to be dead. Of this group approximately 88% had died prior to December 31, 1971.

For the remainder of the cohort, a total of 3800, there was no conclusive evidence available from either the Fund or IRS. At this point, two follow-up procedures were used simultaneously. First, U.S. Postal Service "mailing list correction cards" were sent to the local post offices to ascertain if the study subjects moved to a more recent address than the one shown on the Fund records. Quite often, three or four states may have been involved if there was any mobility. If there was any indication

of a death, a request was made first to the latest address and eventually, if no results were obtained, requests were made to the states of previous residence.

Simultaneously with the "post office follow-up," a request was made to the Social Security Administration data processing section in Woodlawn, Maryland, to provide us with information concerning the study subjects' benefit status. The resulting possibilities were: making contributions to the Social Security fund; receiving benefits from the Fund; death claims filed; no record; or wrong information (incorrect S.S. number, etc.). A miner was assumed to be alive if he was making contributions to the Social Security fund or receiving benefits. If a death claim was filed, Social Security supplied either the state of last residence, state of last claim, or the state of last employment. Death requests were then made to the appropriate state.

Of the 3800 who still had a vital status that was undetermined, 1597 were indicated alive by either Post Office or Social Security. Of this 1597, 70% were identified as alive by both sources. Death certificates were obtained for an additional 1769 miners who were identified as dead either by Social Security or Post Office. In many of these cases it was necessary to send to several different states or have information provided from other sources before the death certificate could be obtained. By this point in the study it became difficult to give credit to one particular source for resolving a case, since many follow-up operations were proceeding simultaneously.

With the above stated sources of vital status information completed the in-depth investigation was initiated for the 434 cases for whom no

definite resolution had been made. Of necessity, because of the time delay between approach and response, some of the steps taken would be overlapping or duplicate effort. Lists of study subjects were mailed first to the district offices, and then to the local union offices of the UMW of A. Any new information was used in conjunction with Postal Service cards and death certificate requests in an attempt to resolve the question of vital status.

Next we matched our "lost to follow-up" cohort to the total study population on the basis of social security number and last known address. Since two workers having social security numbers close in sequence might also indicate proximity of employment at the time numbers were assigned, letters were sent to study subjects whose social security numbers would be close to the "lost to follow-up subject." Letters were also sent to Local Union officers with a proximity in address to those men whose vital status was still unresolved.

Additional methods of follow-up included queries to the widow or other family member of the deceased study subject (determined from earlier advice) asking for a specific place and date of death and inquiries to hospitals, nursing homes or morturaries. Finally, information was obtained from R. L. Polk directories and telephone directories in an attempt to obtain an initial indication of vital status which could be pursued using some of the previously mentioned techniques.

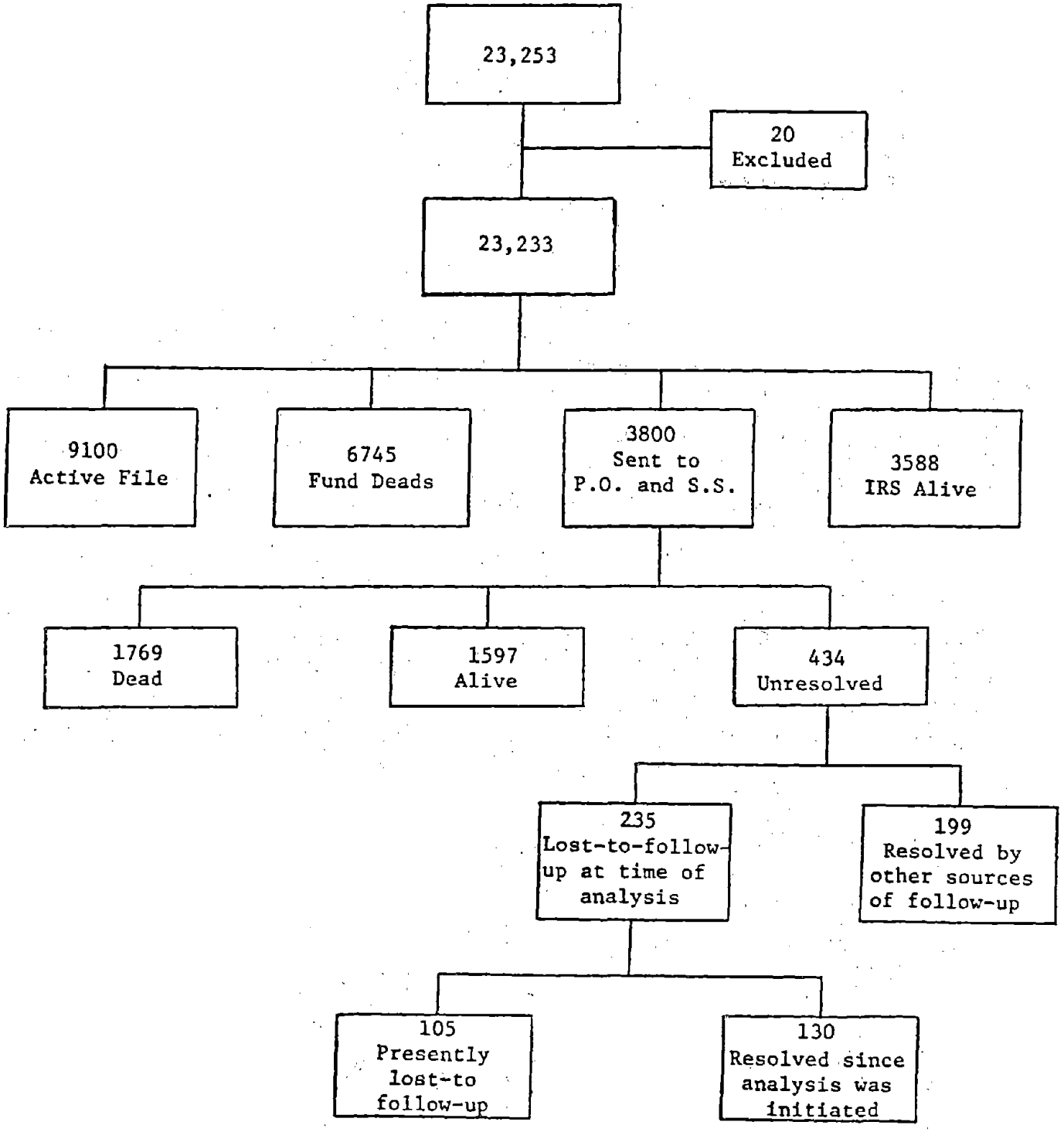
The net result of all of these follow-up procedures is that the vital status of all but 235 of the original cohort were resolved at the time of analysis. Furthermore, due to the long time taken by many of the states to

respond to our requests, we continue to obtain certificates for requests made three months ago. Thus, we now have made vital status determination for an additional 130 miners which when coded and added to the cohort will reduce the number "lost to follow-up" to 105.

Once the vital status was determined, it was necessary to determine which men had died from a specific cause of death. All 7,628 deaths were confirmed by death certificates. Determination and coding of the underlying and contributory causes of death was done by a nosologist trained at the National Vital Statistics Division of the United States Public Health Service in Rockville, Maryland, according to the Seventh Revision of the International List (41).

FIGURE 3.1

Summary of Follow-up as of December 31, 1971



C. Methods of Analysis

Two summary measures of risk are presented in this report to compare cause-specific mortality and to identify those causes showing statistically significant excesses and deficits. The first of these, the Standardized Mortality Ratio (SMR), makes use of an external comparison group. SMR analysis was done using both the total United States male population for the years 1959 through 1971 and the total United States male population in 1965 as control groups.

The SMR's are adjusted for age by the indirect method, utilizing the total U. S. male population as a standard. Age- and cause-specific mortality rates in the standard population were applied to age-specific subgroups of the coal miners at risk in each calendar year of follow-up, 1959-1971, to obtain the number of deaths expected within each subgroup. The SMR is then computed as the ratio of the sum of the observed number of deaths to the sum of the expected number of deaths, summation being taken over calendar year and age-group. Significant deviations from one, indicating excesses or deficits in coal miner mortality relative to the control group, are identified by examining confidence intervals placed on the SMR parameter. Under the assumption of a Poisson distribution of deaths, these bounds are obtained as documented in (42). SMR's are considered to be significantly different from 100, at the 5% level, if their 95% confidence intervals do not contain 100.

Since the observation period for the study spans the time period for part of the Seventh Revision ICD and part of the Eighth Revision ICDA (43),

when using total rates for the years 1959-1971, an adjustment was made so that causes of death coded by the two different revisions would be as comparable as possible. This adjustment was based on a comparability ratio (44), which was computed by using the results of all deaths occurring in 1966 coded according to the Seventh Revision ICD, and a random sample of these same 1966 deaths stratified by cause and coded according to the Eighth Revision ICDA. The ratios were computed by dividing the numbers of deaths estimated from the stratified random sample (coded by the Eighth Revision) by the numbers of deaths assigned to the most comparable causes when coded by the Seventh Revision. Appendix 1 gives those causes of death for which we have comparability ratios and presents the category numbers according to the Seventh Revision ICD and the category numbers of the most comparable category according to the Eighth Revision ICDA. A more detailed description can be found in (44, 45, 46).

Although the use of comparability ratios provides a method of conversion from the Seventh Revision ICD to the Eighth Revision ICDA, there are several disadvantages to this method:

(1) Since the method has not gained widespread use, it remains unfamiliar to many investigators and may be considered by some to be an "unproven" technique.

(2) In addition to being subject to sampling errors, these ratios may have introduced a bias into the results since they were computed using death certificates for both males and females. Furthermore, if the ratio is age-related,

the necessary information is not available to adjust for age differences between the standard and study populations.

(3) The selection of the causes of death to be evaluated is limited to those for which comparability ratios are available.

(4) Although the specific-causes of death can be interpreted individually, when considered as a subcategory of a larger group one obtains the undesirable result that the sum of the expected deaths may not be equal to the sum of the observed. Since many of the comparability ratios are close to 1.0 the deviation of the total expected from the total observed was small compared to the number of deaths being evaluated.

Because of these limitations, all of the Standardized Mortality Ratios were recomputed using the 1965 U.S. male rates. This latter procedure has the advantage of not requiring comparability ratios since both the death certificates and the standard population mortality cases were coded according to the Seventh Revision ICD. Also, for the 1965 rates, a more detailed evaluation for cause of death is possible since we are no longer limited to those causes for which comparability ratios are available. The disadvantage of using only one year as representative of the total observation period is that misleading results could be obtained for diseases which have a trend or which vary from year to year.

Fortunately, the Standardized Mortality Ratios obtained using the

two different control groups identified the same causes of death as excessively high. Therefore, for the coal miners' cohort, the choice of the more appropriate control between these two alternatives is more of an academic question than a practical one.

Unfortunately, complete information on the racial composition of the cohort was not available. For the 7628 individuals who died during the period of observation, examination of the death certificates revealed that 6660 were white (87.3%), 646 were nonwhite (8.5%), and 322 (4.2%) were unknown. Without making unfounded assumptions about the mortality rates of white versus nonwhite coal miners, it is not possible to obtain estimates of the rates for the individual races. As a result, no adjustment is made in the analysis for race. However, all calculations were redone using the total U.S. white male rates. For most causes of death the change in SMR was small (less than 10%). Those causes for which there was a appreciable change will be discussed in the Results Section.

The second measure used in this report, the relative risk, is based upon an internal comparison using the remainder of the miners' cohort. This relative risk and the test of significance associated with it are based on the methods of Mantel and Haenszel (47, 48). This risk represents a weighted average of the odds ratio within each coal miner subgroup and, as such, is actually an approximation to the relative risk. The weights are inversely proportional to the subgroup variances, thereby providing a means of adjusting for any variability that may occur within the control population. Using the total coal miners' cohort as a comparison group, the expected number of deaths for workers in a given subgroup is obtained

by applying the age-adjusted cause-specific mortality rate for the control group to the number of coal miners at risk in the subgroups. The corresponding relative risk, which is adjusted by age and by calendar period of death, is computed for each subgroup of interest, enabling identification of causes showing excess and deficit mortality risks and comparisons between groups to be made. A summary chi-square statistic with one degree of freedom is used to test whether the relative risks are significantly different from one.

Each Fund record has the miner's district number and these can be associated with certain geographical regions. In computing a relative risk a subgroup consisted of those districts which were served by the same area medical office. Thus, we can obtain some comparison between various geographical regions. The local union numbers were also available, but these have changed to such a degree (mergers, etc.) that they could not be used for analytical purposes.

In considering cause-specific mortality of coal miners, some attempt will also be made to take into account the contributory causes of death. It is felt that in an occupational group such as coal miners, diseases may be underreported if only the underlying cause is considered. Therefore, multiple cause of death coding was done for all the miners in the study and an investigation will be conducted in regard to the relative frequencies with which a specific cause is reported as underlying or contributory. The

procedures used in doing the multiple cause of death coding can be found in Appendix I.

In describing the methodology used in the present study, it is important to be aware of some of the limitations of these techniques. The nature of these limitations, which are present in most occupational mortality studies, have been well characterized by others, and will be only briefly summarized here.

First we consider the concept of "statististical significance." Those SMR's found to be "statistically significant" at p = .05 were indicated in the tables. This significance level was used primarily to indicate which causes of death might be of interest for further evaluation. It should be noted that when a large number of tests are conducted, some rejections will occur by chance alone. This is a well known situation and is often referred to as the "problem of multiple comparisons."[49] Also in regard to significance, one must always differentiate between "statistical significance" and "practical significance." Thus, if the sample size is large, even small numerical differences may be statistically significant. However, if variables known to affect mortality for this cause have not been taken into account, are known to produce differences larger than the one observed, the result might not be regarded as having "practical significance." This differentiation is just one manifestation of the fact that a variety of interpretations can be given as to why a particular cause of death has a higher rate

than expectation.

In this study, the comparison group was the total U.S. male population. Since working a job can be considered selective in regard to health, the mortality rate of a working population is typically less than that of the total U.S. population. This effect varies for different occupational groups, and for different causes of death and the reduction in mortality rate for a working population due to the "healthy worker effect" has been estimated by various sources to be in the range of 10% to 40%. Unfortunately, the "healthy worker effect" is confounded with occupational environment and interpretations of an SMR for a working population in the range of 90-110 could vary considerably depending upon how large one assumes the "healthy worker effect" to be.

Finally, one must be conscious of what group the sample can be considered representative. This study is restricted to miners who were members of the United Mine Workers Health and Retirement Funds on Jan. 1, 1959. This includes only bituminous coal miners. Estimates based on our method of sampling indicate that there were approximately 65,00 miners pensioned by the Fund on Jan. 1, 1959 and approximately 165,000 active miners at that time. This latter figure represents more than 90% of the 180,303* men recorded as

*Number obtained from the Bureau of Mines

actively employed in bituminous mines in 1959.

IV. Results

A. Mortality Experience of the Coal Miner Cohort (Underlying Cause)

The total number of miners in the cohort was 23,233. At the time of the analysis, the information as regards vital status was processed for 22,998 of these miners, a group representing 99% of the cohort. Of this number 7628 (33%) died during the period of observation. A listing of the underlying causes of death coded according to the Seventh Revision ICD is given in Appendix II. The unusually high number of deaths for an occupational study of this type is due in part to the age distribution of the cohort (Table 4.1). As indicated in the Table, there are a large number of men in the older age groups, a result of the fact that the cohort consists of both active miners and pensioners. The requirement for pension in 1959 included the restriction that a man be at least 60 years old. In the present section, we evaluate the mortality of the combined group of pensioners and nonpensioners. Comparisons of the mortality patterns between these two groups will be evaluated in the next section.

Guided by the causes for which comparability ratios were available, age-adjusted SMR's were computed for the coal miner cohort for the general causes of death listed in Table 1A of Appendix III. A more detailed breakdown was done for "neoplasms" and "cardiovascular disease" and the specific causes of death within these categories for which an SMR was computed can be found in Tables 1B and 1C of Appendix III. The corresponding SMR's for the 22,998 men in the coal miner cohort are presented in

TABLE 4.1

Distribution of Coal Miners by Age

AGE GROUP	FREQUENCY	PERCENT
ALL AGES	22,998	100.0
<30	1,136	4.9
30-34	1,720	7.5
35-39	2,300	10.0
40-44	2,414	10.5
45-49	2,681	11.7
50-54	2,298	10.0
55-59	2,111	9.2
60-64	2,030	8.8
65-69	2,382	10.4
70-74	2,103	9.1
75+	1,823	7.9

Tables 4.2A, 4.2B, and 4.2C.

The cohort shows excess mortality from "accidents" and from many of the nonmalignant respiratory diseases. Influenza, emphysema, asthma, and tuberculosis all result in significantly high SMR's. Ill-defined causes and the category "all other causes" are also significantly high, while diabetes, peptic ulcer, cirrhosis, and cardiovascular disease reveal significantly low SMR's.

1. Malignant Neoplasms - The observed and expected numbers of deaths for neoplasms were 1223 and 1252.2, respectively, yielding an SMR of 97.7. The more detailed breakdown presented in Table 4.2B shows that the only cancer which are significantly high are those of the respiratory organs with an SMR of 112.5. Of the 373 deaths from respiratory cancers, 352 were classified as cancer of the lung (ICD 162-162). Although the excess due to respiratory cancer was significantly high, it could be related to nonoccupational factors. The SMR of 112.5 is well within the range of what might result from differences in residence or smoking habits of the control and study groups (42).

Also of interest is the category of digestive cancers. One of the few results agreed upon by all previous investigators is the high incidence of stomach cancer noted in coal miners (21, 29, 35, 36). SMR's were computed for stomach (151) and colon (153) cancer separately, using comparability ratios of 1.02 and 1.01 (46). The SMR for stomach cancer was 134.9 ($P < .05$), while for colon cancer, the SMR of 70.9 was significantly low. The remainder of the digestive cancers considered as a group revealed mortality close to expectation (SMR = 99.1). A number

TABLE 4.2A

Observed and Expected Deaths, and Standardized Mortality Ratios for Coal Miners for Selected Causes of Death (N = 22,998)

CAUSE OF DEATH	Obs.	Exp.	SMR*
All Causes	7628	7506.1	101.6
All Malignant Neoplasms	1223	1252.2	97.7
Benign and Unspecified Neoplasms	14	14.4	97.5
Major Cardiovascular Diseases	4285	4501.2	95.2*
Bronchitis	27	31.5	84.8
Acute Bronchitis and Bronchiolitis	1	2.5	—
Chronic and Unqualified Bronchitis	26	29.0	89.7
Influenza	28	14.8	189.6*
Pneumonia	217	232.3	93.4
Emphysema	170	118.3	143.7*
Asthma	32	18.3	174.9*
Tuberculosis	63	43.3	145.5*
Syphilis	16	13.1	122.3
Other Infective and Parasitic Diseases	13	17.6	74.1
Diabetes Mellitus	64	110.2	58.1*
Peptic Ulcer	42	58.7	71.6*
Cirrhosis of Liver	64	104.9	61.0*
Cholelithiasis, Cholecystitis, and Cholangitis	22	16.7	132.0
Nephritis and Nephrosis	42	46.2	91.0
Accidents	408	283.0	144.2*
Suicides	81	81.3	99.6
Homicides	30	26.1	115.1
Ill-Defined Causes	162	86.2	187.9*
All Other Causes	625	459.5	136.0*

* Standardized Mortality Ratio (SMR) is significantly different from 100 at the 5% level.

TABLE 4.2B

Observed and Expected Deaths, and Standardized Mortality Ratios for Coal Miners for Selected Causes of Malignant Neoplasms (N = 22,998)

CAUSE OF DEATH	Obs.	Exp.	SMR*
All Malignant Neoplasms	1223	1252.2	97.7
Buccal Cavity and Pharynx	31	37.8	81.9
Digestive Organs and Peritoneum	408	419.8	97.2
Respiratory Organs	373	331.5	112.5*
Breast	0	1.9	--
Genital Organs	124	151.0	82.1*
Urinary Organs	66	75.8	87.1
Leukemia and Aleukemia	50	50.0	100.7
Other Lymphatic and Hematopoietic	58	57.8	100.4
All Other Sites	113	125.3	90.2
Benign and Unspecified Neoplasms	14	14.4	97.5

* Standardized Mortality Ratio (SMR) is significantly different from 100 at the 5% level.

TABLE 4.2C

Observed and Expected Deaths, and Standardized Mortality Ratios for Coal Miners for Selected Causes of Cardiovascular Disease (N = 22,998)

CAUSE OF DEATH	Obs.	Exp.	SMR*
Major Cardiovascular Diseases	4285	4501.2	95.2*
Active Rheumatic Fever and Chronic Rheumatic Heart Disease	35	46.8	74.9
Hypertensive Heart Disease	213	199.4	106.8
Ischemic Heart Disease	2823	2922.2	96.6
Chronic Disease of Endocardium and Other Myocardial Insufficiency	38	56.7	67.0*
All Other Forms of Heart Disease	133	136.2	97.6
Hypertension	58	49.5	117.1
Cerebrovascular Disease	802	832.3	96.4
Arteriosclerosis	133	159.0	83.6*
Other Diseases of Arteries, Arterioles, and Capillaries	50	76.6	65.3*

* Standardized Mortality Ratio (SMR) is significantly different from 100 at the 5% level.

of nonoccupational variables have been related to stomach cancer in the literature including socio-economic status, ethnic background, geographic region, and diet. The only study mentioned in this report which controlled for these variables was the one reported by Matalo (36), and he still obtained a significantly high SMR for stomach cancer. The low incidence of colon cancer is also consistent with his results.

2. Cardiovascular Disease - The observed and expected numbers of deaths for cardiovascular diseases were 4285 and 4501.2, respectively. No subcategory had an SMR that was significantly high, and only two, hypertensive heart disease and hypertension, showed SMR's greater than 100. Since hypertension is known to be higher in blacks, some type of adjustment for race could be more important here than for other causes. The SMR's for hypertension and hypertensive heart disease were recomputed using the total U.S. male rates for whites. The results showed an SMR of 130.3 for hypertension and 124.1 for hypertensive heart disease, the latter being significant ($P < .05$). It should be emphasized that the SMR's based on the white rates give an upper bound for the true SMR, with the true values probably lying between the values obtained using the total U.S. male rates and the white male U. S. rates.

3. Nonmalignant Respiratory Disease - The coal miners showed excessive mortality from most of the nonmalignant respiratory diseases. Unfortunately, comparability ratios were not available for many of the subcategories of interest. Of those which could be computed, influenza, emphysema, asthma, and tuberculosis all resulted in significantly high SMR's ($P < .05$). Only pneumonia and bronchitis showed SMR's lower than

expectation (93.4 and 84.8, respectively). The remaining nonmalignant respiratory diseases were grouped with all other causes, providing an explanation for the observed high SMR (136.0). Of the 625 deaths in the category "all other causes", 299 were due to nonmalignant respiratory diseases, and of these, 187 were due to pneumoconiosis (ICD 523-524) for which no rates were available.

4. Diseases with a low SMR - It is interesting to note that diabetes, peptic ulcer, and cirrhosis all yielded significantly low SMR's. The result for diabetes is not surprising since this was one of the few diseases reported as having a low SMR in the study based upon the 1950 census (28, 29).

5. Accidents - The observed and expected numbers of deaths due to accidents were 408 and 283.0, respectively, resulting in a significantly high SMR of 144.2. Within this group, 103 were killed in mine diasters or cave-ins. Eliminating these 103 deaths from the computations reduces the SMR for accidents to 107.8, which is not significantly greater than 100 at the 5% level.

6. Ill-defined Causes - The high SMR for ill-defined causes may be due to the characteristics of the areas in the country in which coal mining communities are usually located. In these generally more rural areas, the proportion of death certificates that do not indicate a specific cause of death tends to be higher than the proportion in urban areas.

7. All Other Causes - As was mentioned previously, the high SMR noted for this category is probably related, to a large degree, to the

inclusion of 299 deaths from nonmalignant respiratory diseases. Unfortunately, the comparability ratios which were necessary for a more detailed evaluation were not available.

The lack of availability of comparability ratios for some of the causes of death is one of the main reasons for redoing the analysis using the 1965 total U.S. male rates. A summary of the observed and expected deaths and SMR's for selected causes of death using this comparison group is presented in Table 4.3A. More detailed breakdowns for "neoplasms", "cardiovascular diseases", and nonmalignant respiratory diseases" are provided in Tables 4.3B, 4.3C and 4.3D.

A comparison of the SMR's using the 1965 rates to Tables 4.2A 4.2B, and 4.2C show the results to be quite similar. The only significant change occurred for influenza, where the SMR increased to 348.6. This change is most probably a function of the large year-to-year variation in mortality from this cause and the fact that in 1965 the death rate was relatively low; for the years 1960, 1963, 1968, and 1969, the U.S. death rates for influenza for many age groups were four times as high as the 1965 rates.

As suggested previously, removing the nonmalignant respiratory diseases from the category "all other causes" reduces the SMR, the resulting value of 79.0 being significantly low. The SMR for the category "nonmalignant respiratory diseases" is 157.1 and is statistically significant ($P < .05$). A more detailed breakdown of the causes of death within the nonmalignant respiratory disease category is shown in Table 4.3D. As was mentioned earlier in this report, the SMR for influenza is misleading since the 1965 total U.S. male rate for this cause was low. Primary atypical pneumonia

TABLE 4.3A

Observed and Expected Deaths and Standardized Mortality Ratios for Coal Miners for Selected Causes of Death using 1965 Total U.S. Male Population as Standard.

CAUSE OF DEATH	Observed	Expected	SMR*
All Causes	7628	7546.6	101.1
All Malignant Neoplasms	1223	1248.2	98.0
Benign and Unspecified Neoplasms	14	14.8	94.3
Major Cardiovascular Diseases	4285	4525.9	94.7*
Nonmalignant Respiratory Diseases	741	471.6	157.1*
Asthma	32	19.3	166.0*
Tuberculosis	63	42.6	148.0*
Infective and Parasitic Diseases	29	30.3	95.8
Accidents	408	286.8	142.3*
Homicides and Suicides	111	106.4	104.4
Ill-Defined Causes	162	91.5	177.1*
All Other Causes	560	709.2	79.0*

* Standardized Mortality Ratio (SMR) is significantly different from 100 at the 5% level.

TABLE 4.3B

Observed and Expected Deaths and Standardized Mortality Ratios for Coal Miners for Selected Malignant Neoplasms using 1965 Total U.S. Male Population as Standard.

CAUSE OF DEATH	Observed	Expected	SMR*
All Malignant Neoplasms	1223	1248.2	98.0
Buccal Cavity and Pharynx	31	37.1	83.6
Digestive Organs and Peritoneum	408	417.2	97.8
Stomach	127	91.9	138.2*
Colon	86	123.0	69.9*
Other Digestive Cancers	195	202.2	96.4
Respiratory Organs	373	331.9	112.4*
Lung	352	309.5	113.7*
Other Respiratory Cancers	21	22.4	93.7
Genital Organs	124	150.1	82.6*
Urinary Organs	66	73.7	89.6
Leukemias	108	106.6	101.3
All Other Sites	113	131.6	85.9

* Standardized Mortality Ratio (SMR) is significantly different from 100 at the 5% level.

TABLE 4.3C

Observed and Expected Deaths and Standardized Mortality Ratios for Coal Miners for Selected Cardiovascular Diseases using 1965 Total U.S. Male Population as Standard.

CAUSE OF DEATH	Observed	Expected	SMR*
Major Cardiovascular Diseases	4285	4525.9	94.7*
Active Rheumatic Fever and Chronic Rheumatic Heart Disease	35	43.2	80.9
Hypertensive Heart Disease	213	199.5	106.8
Ischemic Heart Disease	2823	2981.4	94.7*
Chronic Disease of Endocardium and Other Myocardial Insufficiency	38	54.2	70.1*
All Other Forms of Heart Disease	133	128.9	103.2
Hypertension	58	49.8	116.6
Cerebrovascular Disease	802	823.1	97.4
Arteriosclerosis	133	164.7	80.8*
Other Diseases of Arteries, Arterioles, and Capillaries	50	81.1	61.6*

* Standardized Mortality Ratio (SMR) is significantly different from 100 at the 5% level.

TABLE 4.3D

Observed and Expected Deaths and Standardized Mortality Ratios for Coal Miners for Selected Nonmalignant Respiratory Diseases using 1965 Total U.S. Male Population as Standard.

CAUSE OF DEATH	Observed	Expected	SMR*
Nonmalignant Respiratory Diseases	741	471.6	157.1*
Influenza	28	8.0	348.6*
Pneumonia	217	237.4	91.4
Lobar Pneumonia	34	39.9	85.1
Bronchopneumonia	122	136.0	89.7
Primary Atypical Pneumonia	23	12.8	179.7*
Pneumonia, Unspecified	38	48.6	78.3
Bronchitis	27	31.8	85.0
Acute Bronchitis	1	2.9	--
Chronic Bronchitis	26	28.9	90.0
Chronic Interstitial Pneumonia	58	16.4	353.7*
Bronchiectasis	11	9.0	122.1
Emphysema Without Mention of Bronchitis	170	134.6	126.3*
Pneumoconiosis	187	(20.2)	(925.7)*
Other Nonmalignant Respiratory Diseases	43	34.4	125.0

* Standardized Mortality Ratio (SMR) is significantly different from 100 at the 5% level.

Parentheses indicate conservative estimates -- see text.

(ICD 492) and chronic interstitial pneumonia (ICD 525) are high, but these diseases are too nonspecific to attribute to particular causes. Bronchitis, found to be high in some previous studies, has an SMR of 85.0. It is interesting to note, however, that all of the deaths attributed to chronic bronchitis also mentioned emphysema (ICD 502). Emphysema as an underlying cause of death without mention of bronchitis (ICD 527.1) was also significantly high (126.3, $P < .05$). The largest SMR was for pneumoconiosis (ICD 523, 524). Since standard rates for the total U.S. population are not available for this cause of death, it is not possible to compute an actual SMR. Therefore, the SMR was computed by using as a comparison the combined rates of causes of death 511-517, 520, 522-524, the smallest disease category available which contains pneumoconiosis as a subcategory. Thus, the SMR of 925.7 is conservative.

B. Mortality of Pensioners vs. Nonpensioners

It was noted earlier in this report that the cohort of 22,998 coal miners included men who were already pensioned on January 1, 1959. Some of the problems associated with drawing inferences about a working population from a group of retirees have been discussed elsewhere (50, 51, 52, 53). Obviously, the pensioners are a select group in that they consist only of those men who have survived long enough to retire. In view of this, an attempt was made in this study to identify those miners who were pensioned on January 1, 1959 and, using this information to compare the mortality experiences of the pensioned men and the nonpensioned men.

The 085 card (the record which was microfilmed) for each miner indicated whether or not he was receiving a pension but, unfortunately, did not provide the pension date. As a result, it was necessary to decide on a criterion for determining which of the miners listed as pensioned did, in fact, hold this status on January 1, 1959. To do this, it was assumed that all miners retired as soon as they were eligible to do so which, in 1959, was at age 60. While there were, undoubtedly, exceptions to this, the assumption appears to be a reasonable one. Thus, all miners in the cohort who were 60 years old as of January 1, 1959 and whose 085 card indicated a pension, were considered to be in the pensioner cohort. The resulting number of men satisfying these conditions in the cohort is 6524, which compares favorably with a figure representing 10% of the pensioners which the Fund had on record as of July 1, 1959, or approximately 6549 men (54).

Once the pensioner group was identified, Standardized Mortality Ratios were computed for both the pensioner and nonpensioner cohorts

using total U.S. male rates. The results for the nonpensioner cohort are shown in Tables 4.4A, 4.4B, and 4.4C, while those for the pensioner cohort are presented in Tables 4.5A, 4.5B, and 4.5C.

The nonpensioner group showed an SMR of 106.1 ($P < .05$), and this was higher than the SMR of 98.3 obtained in the pensioner group. The pensioners tend to show slightly higher mortality from cancers, but their overall SMR from all malignant neoplasms is only 104.6. In fact, the only neoplasm for which observed deaths exceed expected deaths in both groups is respiratory cancer, where the SMR for the pensioners is 115.8 and for the nonpensioners is 109.9. Although the SMR for all digestive cancers was significantly low for the nonpensioners, a further breakdown for selected sites showed the same pattern as for the total cohort; the SMR's for stomach and colon cancer were 111 and 62, respectively. An even larger difference was apparent in the pensioned group, where the SMR for stomach cancer was 151, compared to an SMR of 77 for colon cancer.

An examination of the SMR's for cardiovascular disease also showed a slight difference between the pensioner and nonpensioner cohorts. With the exception of rheumatic fever, the pensioners' SMR's were lower than those of the nonpensioners for all subcategories of cardiovascular disease. However, this is primarily due to the deficit of heart disease in the pension group (chronic disease of endocardium 49.4, arteriosclerosis 70.5, cerebrovascular disease 91.4) rather than to an excess in the nonpensioned cohort.

For nonmalignant respiratory diseases the pattern observed when evaluating the total cohort appears to be true for both the pensioned and

nonpensioned subgroups. Namely, high SMR's for influenza, emphysema, asthma and tuberculosis. Bronchitis and pneumonia are not higher than expectation for either cohort. The largest differences between the two cohorts appeared for influenza and tuberculosis, both of which showed higher SMR's in the nonpensioned cohort.

One of the more pronounced differences in cause specific mortality between pensioners and nonpensioners was for accidents. Of the total number of deaths from this cause, 164 occurred in the mine. Since the pensioners are not at risk for occupational accidents, it would be more appropriate to use the SMR of 181.0 for the nonpensioned group in depicting the SMR of the U.S. coal miner for this cause of death. If mine disasters and cave-ins are eliminated, the observed number of deaths for the nonpensioned group is reduced to 216 with a corresponding SMR equal to 122.5. If, in addition, all accidents occurring at the mine are eliminated, the observed number of deaths is 164 and the SMR is 93.0.

Other causes which were higher in the nonpensioned group included ulcers and nephritis. The pensioners showed higher mortality than the nonpensioners for cirrhosis and cholelithiasis. Diabetes showed a significantly low mortality in both the pensioned and nonpensioned group (55.0 and 62.2, respectively).

Subsequent to this analysis, we decided to verify our assumption that most of the men who had been listed as pensioned by the Fund records and who had been 60 or over by January 1, 1959, were, in fact, pensioners. Using information in a separate file, we obtained the date the first pension check was issued for the 6524 men included in our pensioner cohort, i.e., the men we

believed to be pensioners at the initial date of the study. The resulting number of men who were receiving pension checks prior to January 1, 1959 was 5836. Since in some cases retirement occurred before the first pension check was issued, the actual number of men in the cohort who were retired as of January 1, 1959 probably lies between 5836 and 6524. The Standardized Mortality Ratios for the 5836 men were recalculated and in no case did a cause of death show an SMR that differed by more than 10% from that obtained using the pension group based on birth year.

Table 4.4A

Observed and Expected Deaths, and Standardized Mortality Ratios for Nonpensioned Coal Miners for Selected Causes of Death (N = 16,474)

CAUSE OF DEATH	Obs.	Exp.	SMR*
All Causes	3392	3197.8	106.1*
All Malignant Neoplasms	529	588.9	89.8*
Benign and Unspecified Neoplasms	8	8.0	100.0
Major Cardiovascular Diseases	1738	1740.7	99.8
Bronchitis	13	13.2	98.5
Acute Bronchitis and Bronchiolitis	1	1.1	--
Chronic and Unqualified Bronchitis	12	11.8	101.6
Influenza	12	5.2	232.6*
Pneumonia	70	80.6	86.9
Emphysema	70	50.4	138.8*
Asthma	14	8.6	163.2
Tuberculosis	36	22.4	160.9*
Syphilis	7	5.9	117.9
Other Infective and Parasitic Diseases	4	9.1	43.7
Diabetes Mellitus	29	46.6	62.2*
Peptic Ulcer	24	26.1	91.9
Cirrhosis of Liver	28	76.4	36.6*
Cholelithiasis, Cholecystitis, and Cholangitis	4	5.5	72.6
Nephritis and Nephrosis	24	21.7	110.7
Accidents	319	176.3	181.0*
Suicides	53	57.1	92.9
Homicides	26	23.2	111.9
Ill-Defined Causes	98	42.2	232.4*
All Other Causes	286	203.7	140.4*

* Standardized Mortality Ratio (SMR) is significantly different from 100 at the 5% level.

Table 4.4B

Observed and Expected Deaths, and Standardized Mortality Ratios for Nonpensioned Coal Miners for Selected Causes of Malignant Neoplasms (N = 16,474)

CAUSE OF DEATH	Obs.	Exp.	SMR*
All Malignant Neoplasms	529	588.9	89.8*
Buccal Cavity and Pharynx	12	20.4	59.0
Digestive Organs and Peritoneum	148	182.0	81.3*
Respiratory Organs	205	186.5	109.9
Breast	0	0.9	--
Genital Organs	29	44.2	65.7*
Urinary Organs	29	31.9	90.8
Leukemia and Aleukemia	24	22.1	108.9
Other Lymphatic and Hematopoietic	30	31.6	94.9
All Other Sites	52	67.7	76.8
Benign and Unspecified Neoplasms	8	8.0	100.0

* Standardized Mortality Ratio (SMR) is significantly different from 100 at the 5% level.

Table 4.4C

Observed and Expected Deaths, and Standardized Mortality Ratios for Nonpensioned Coal Miners for Selected Causes of Cardiovascular Disease (N = 16,474)

CAUSE OF DEATH	Obs.	Exp.	SMR*
Major Cardiovascular Diseases	1738	1740.7	99.8
Active Rheumatic Fever and Chronic Rheumatic Heart Disease	22	30.2	72.8
Hypertensive Heart Disease	86	72.2	119.1
Ischemic Heart Disease	1173	1195.6	98.1
Chronic Disease of Endocardium and Other Myocardial Insufficiency	20	20.3	98.6
All Other Forms of Heart Disease	65	58.9	110.3
Hypertension	22	17.9	122.9
Cerebrovascular Disease	282	263.4	107.1
Arteriosclerosis	47	37.1	126.8
Other Diseases of Arteries, Arterioles, and Capillaries	21	30.8	68.2

* Standardized Mortality Ratio (SMR) is significantly different from 100 at the 5% level.

Table 4.5A

Observed and Expected Deaths, and Standardized Mortality Ratios for Pensioned Coal Miners for Selected Causes of Death (N = 6524)

CAUSE OF DEATH	Obs.	Exp.	SMR*
All Causes	4236	4308.0	98.3
All Malignant Neoplasms	694	663.4	104.6
Benign and Unspecified Neoplasms	6	6.4	94.4
Major Cardiovascular Diseases	2547	2760.5	92.3*
Bronchitis	14	18.3	76.3
Acute Bronchitis and Bronchiolitis	0	1.4	--
Chronic and Unqualified Bronchitis	14	17.2	81.4
Influenza	16	9.6	166.5
Pneumonia	147	151.7	96.9
Emphysema	100	67.9	147.4*
Asthma	18	9.7	185.2
Tuberculosis	27	20.9	129.1
Syphilis	9	7.1	125.9
Other Infective and Parasitic Diseases	9	8.4	107.1
Diabetes Mellitus	35	63.6	55.0*
Peptic Ulcer	18	32.6	55.3*
Cirrhosis of Liver	36	28.5	126.5
Cholelithiasis, Cholecystitis, and Cholangitis	18	11.2	161.3
Nephritis and Nephrosis	18	24.5	73.5
Accidents	89	106.7	83.4
Suicides	28	24.3	115.3
Homicides	4	2.8	--
Ill-Defined Causes	64	44.0	145.4*
All Other Causes	339	255.8	132.5*

* Standardized Mortality Ratio (SMR) is significantly different from 100 at the 5% level.

Table 4.5B

Observed and Expected Deaths, and Standardized Mortality Ratios for Pensioned Coal Miners for Selected Causes of Malignant Neoplasms (N = 6524)

CAUSE OF DEATH	Obs.	Exp.	SMR*
All Malignant Neoplasms	694	663.4	104.6
Buccal Cavity and Pharynx	19	17.5	108.7
Digestive Organs and Peritoneum	260	237.8	109.3
Respiratory Organs	168	145.0	115.8
Breast	0	1.0	--
Genital Organs	95	106.8	88.9
Urinary Organs	37	43.8	84.4
Leukemia and Aleukemia	26	27.6	94.2
Other Lymphatic and Hematopoietic	28	26.2	107.1
All Other Sites	61	57.6	106.0
Benign and Unspecified Neoplasms	6	6.4	94.4

* Standardized Mortality Ratio (SMR) is significantly different from 100 at the 5% level.

Table 4.5C

Observed and Expected Deaths, and Standardized Mortality Ratios for Pensioned Coal Miners for Selected Causes of Cardiovascular Disease
(N = 6524)

CAUSE OF DEATH	Obs.	Exp.	SMR*
Major Cardiovascular Diseases	2547	2760.5	92.3*
Active Rheumatic Fever and Chronic Rheumatic Heart Disease	13	16.6	78.6
Hypertensive Heart Disease	127	127.2	99.9
Ischemic Heart Disease	1650	1726.7	95.6
Chronic Disease of Endocardium and Other Myocardial Insufficiency	18	36.4	49.4*
All Other Forms of Heart Disease	68	77.3	88.0
Hypertension	36	31.6	113.8
Cerebrovascular Disease	520	568.8	91.4*
Arteriosclerosis	86	122.0	70.5*
Other Diseases of Arteries, Arterioles, and Capillaries	29	45.8	63.4*

* Standardized Mortality Ratio (SMR) is significantly different from 100 at the 5% level.

C. Mortality Patterns For Multiple Cause of Death

In this, as in most other mortality studies, the interpretation of the data has depended solely upon the underlying cause of death. However, additional mortality information may also be recorded on the death certificate in the form of "disease or condition directly leading to death", "antecedent cause", or "other significant condition". We will loosely refer to these as "contributory causes of death". The need for taking data of this nature into account has been reported by several authors (55, 56, 57). Although there is no generally accepted way of handling multiple cause of death data, one method which has been suggested is to compute the ratio of the total number of times a particular cause is coded (sum of underlying and contributory) to the number of cases for which the same cause appears as underlying.

Tabulations of this nature have been reported by Guralnick (58) for a one-third sample of the deaths occurring in the United States during 1955, and by Olson et al (59), for a fifty percent sample of the deaths in the state of California during the same year. In a group such as the coal miners, these ratios would be of interest since many of the nonmalignant respiratory diseases may not appear as the underlying cause of death. A ratio substantially larger than one could indicate an underreporting of cause-specific mortality if only the underlying cause were used. Furthermore, it may be possible that, for a particular occupational group, the cause is present on the same number of death certificates as for the control population but it does not occur as an underlying cause the same proportion of times.

The ratios of total deaths to underlying deaths for the causes listed in Table 1 of Appendix IV were computed individually for whites and nonwhites. A total ratio for each cause was computed by forming the quotient of the sum of total deaths for whites and nonwhites with the sum of the underlying deaths for whites and nonwhites. In computing the frequency of the total deaths (underlying and contributory), distinctions were made only for the first three digits of the ICD.

The number of causes coded per death usually increases with age, since deaths at older ages are more likely to involve multiple causes. The ratios for the age groups <35, 35-44, 45-54, 55-64, and 65+ are, respectively, 1.12, 1.30, 1.48, 1.78, and 2.07. Tables of these ratios by age and by race for selected causes of death can be found in Appendix IV. A summary of these tables over all age groups is presented in Table 4.6 The ratios for the two races are similar. The largest difference occurs for diabetes where the ratio is more than twice as high for whites as for nonwhites (4.84 compared to 2.25). Other than diabetes, the causes which show the greatest differences between the races are hypertensive heart disease, pneumonia, bronchitis, pneumoconiosis, tuberculosis, and cirrhosis.

The ratios given in Table 4.6 are in close agreement with the results of Guralnick (58) and Olson (59). Table 4.7 compares these two studies with the coal miner cohort for selected causes of death. The lower ratios for coal miners for respiratory disease could be due to the fact that coal miners have respiratory disease as the underlying cause much more than the

TABLE 4.6

Frequencies of Primary and Total (Primary and Contributory) Causes of Death for All Coalminers by Cause and by Race

CAUSE OF DEATH	WHITE			NONWHITE			TOTAL		
	Primary	Total	Ratio*	Primary	Total	Ratio*	Primary	Total	Ratio*
All Causes	6660	12,986	1.95	646	1287	1.99	7306	14,273	1.95
All Malignant Neoplasms	1099	1,259	1.15	92	112	1.22	1191	1,371	1.15
Digestive Organs and Peritoneum	376	416	1.11	20	24	1.20	396	440	1.11
Lung, Bronchus, Trachea	317	341	1.08	32	34	1.06	349	375	1.07
All Other Sites	406	502	1.24	40	54	1.35	446	556	1.25
Cardiovascular-Renal Disease	3889	7,486	1.92	356	728	2.04	4245	8,214	1.93
Vascular Lesions Affecting CNS	692	1,249	1.80	74	136	1.84	766	1,385	1.81
Arteriosclerotic & Degenerative Heart Disease	2584	3,310	1.28	183	244	1.33	2767	3,554	1.28
Hypertensive Heart Disease	164	305	1.86	45	64	1.42	209	369	1.77
Other Hypertensive Disease	47	204	4.34	8	34	4.25	55	238	4.33
General Arteriosclerosis **	121	1,051	8.69	9	95	10.56	130	1,146	8.82
Chronic Nephritis	34	84	2.47	3	8	2.67	37	92	2.49
All Other Cardiovascular-Renal Disease	247	1,283	5.19	34	147	4.32	281	1,430	5.09
Diabetes Mellitus	51	247	4.84	12	27	2.25	63	274	4.35

* Ratio = Total/Primary

** Those cases where 4500 was coded in conjunction with 4221 were not used in the numerator of the ratio. This also applies to the tables in Appendix III.

TABLE 4.6 (Cont'd.)

CAUSE OF DEATH	WHITE			NONWHITE			TOTAL		
	Primary	Total	Ratio*	Primary	Total	Ratio*	Primary	Total	Ratio*
Nonmalignant Respiratory Disease	650	2,035	3.13	72	221	3.07	722	2,256	3.12
Upper Respiratory Infections and Influenza	25	33	1.32	3	3	1.00	28	36	1.29
Pneumonia	188	435	2.31	25	45	1.80	213	480	2.25
Bronchitis	22	86	3.91	4	11	2.75	26	97	3.73
Pneumoconiosis and Pulmonary Fibrosis of Occupational Origin	165	504	3.05	14	57	4.07	179	561	3.13
All Other Nonmalignant Respiratory Disease	250	977	3.91	26	105	4.04	276	1,082	3.92
Tuberculosis	47	93	1.98	14	20	1.43	61	113	1.85
Syphilis	12	21	1.75	3	4	1.33	15	25	1.67
Ulcer of Stomach	21	43	2.05	2	5	2.50	23	48	2.09
Cirrhosis of Liver	55	99	1.80	5	7	1.40	60	106	1.77
Accidents	302	363	1.20	26	29	1.12	328	392	1.20
Suicides	78	78	1.00	1	1	1.00	79	79	1.00
Homicides	19	19	1.00	11	11	1.00	30	30	1.00
All Other Causes	437	1,243	2.84	52	122	2.35	489	1,365	2.79

* Ratio = Total/Primary

TABLE 4.7

Comparison of the Total/Primary Ratios among Three Studies

Cause of death	Guralnick's Study	Olson's Study	Coal Miner Study
All causes	1.91	2.05	1.95
Digestive cancer	1.05	1.08	1.15
Lung cancer	1.04	1.04	1.07
Diabetes mellitus	2.46	3.18	4.35
Stroke	1.75	1.95	1.81
ADH **	1.32	1.34	1.28
Hypertensive disease	2.50	2.69	1.77
General arteriosclerosis *	7.50	6.03	8.82
Respiratory disease	3.79	4.46	3.12
Pneumonia	2.76	3.57	2.25
Accidents	1.22	1.18	1.20

* Those cases where 4500 was coded in conjunction with 4221 were not used in the numerator of the ratio.

** ADH stands for Arteriosclerotic and Degenerative Heart Disease.

general population. It could also, however, indicate that the physician is more likely to certify respiratory disease as the underlying cause if he is dealing with a coal miner.

Perhaps the most interesting comparison is that for diabetes. One possibility for the large difference is that the groups may have different racial compositions; another possibility is that the coal miners may have just as much diabetes as the control group but it is not being coded as the underlying cause. Diabetes is particularly interesting in coal miners because it has aroused speculation as to why mortality is low in this group and a selection factor has been suggested (29). One answer could be that its incidence is not low but that it simply does not appear as often as an underlying cause. An examination of the death certificates of coal miners who died from diabetes showed no unusual pattern but, unfortunately, the necessary information for a proper comparison with an appropriate control group is not available. The ratios for hypertensive heart disease also differed for the coal miner cohort. The reason for this is unclear, but one possibility may be a difference in racial composition.

D. Analysis by District

The coal miners in the cohort were employed in different geographic locations. At present, the best indication we have of the geographic location is the district union number. Frequencies of the number of miners by last district of employment are shown in Table 4.8. Since the number within each district is sometimes too small for analytical purposes, the districts have been grouped together according to their area medical office.* The cities given in the Table are the locations of the offices, but the geographic area covered by the districts served by each medical office may be quite large. Table 1 of Appendix V summarizes the approximate geographic locations (60) of the districts associated with each medical office.

Relative risks for each area were computed for the causes presented in Tables 2A, 2B, and 2C of Appendix V. For each comparison, the remainder of the coal miner cohort was used as a control, and a Mantel-Haenszel chi-square test with one degree of freedom was used to determine if the relative risk was significantly different from one. Tables showing the relative risks by medical area for the more important of these causes are given in Appendix V.

1. All Causes - Although some of the relative risks for all causes differ significantly from one, the range of values is not great. The largest value is 1.15 for Evansville and the lowest is .80 for Denver.

* These medical offices are the assignments in 1973. Recently, the Fund has consolidated the ten areas into seven.

TABLE 4.8

Frequencies of Coal Miners in the Cohort by District Union Number

	District Number	
Beckley	29	3188
Birmingham	20	1105
Charleston	17	2643
Denver	10*	72
	15	336
	22	376
	27*	111
Evansville	8*	13
	11	626
	23	602
Johnstown	2	2217
Knoxville	19	1232
	28	836
	30	1642
Morgantown	4	1282
	16**	39
	31	1465
Pittsburgh	3	286
	5	1866
	6	1186
St. Louis	12	1461
	13**	44
	14	142
	21	217
Unknown	--	11

* No longer in existence

** District 16 was in Maryland and now is part of 31.
District 13 was in Iowa and now is part of 14.

2. All Cancers - The relative risks for all cancers show a larger difference. Both Charleston (Relative Risk = 1.30) and Pittsburgh (Relative Risk = 1.30) are significantly high ($P < .01$). A more detailed analysis revealed that the high cancer risk in Pittsburgh was due primarily to high risk of digestive cancers (Relative Risk = 1.50) and of cancers of unspecified sites. For Charleston, the excess was primarily due to lung cancer (Relative Risk = 1.72). It should be emphasized that these differences could be reflecting the differences in mortality patterns for the total populations of the different areas rather than differences in the coal mining population. Thus, the excess of digestive cancers in the Pittsburgh area is probably reflecting, to some extent, the high rate observed for the total population of that area (61).

3. Cardiovascular Disease - The highest relative risk for cardiovascular disease occurred for Evansville (Relative Risk = 1.25), where the excess appears to be due primarily to an increased risk of dying from ischemic heart disease. The only other subcategories which showed unusually high risks for any district were cerebrovascular disease (1.80 in Birmingham), rheumatic heart disease (2.40 in Pittsburgh) and the categories "all other heart disease" and hypertensive heart disease (3.04 and 1.88, respectively, in Beckley).

4. Nonmalignant Respiratory Diseases - Miners in the Beckley (Relative Risk = 1.47) and Johnstown (Relative Risk = 1.57) districts showed significantly high risks of dying from nonmalignant respiratory diseases ($P < .01$). The high risk in Johnstown was due

almost solely to pneumoconiosis (Relative Risk = 4.22), while in Beckley, both emphysema and pneumoconiosis were high with respective risks of 2.03 and 1.64. The relative risk of 2.60 for bronchitis in Beckley was also significant, but this was based only on 7 observed and 3.2 expected deaths. The other high relative risks of note occurred for emphysema in Denver, where the risk was 1.88, and for other nonmalignant respiratory diseases in Knoxville, where the risk was 1.71.

5. Ill-defined Causes - Excess mortality from ill-defined causes appeared in the Birmingham and Charleston districts, as indicated by the respective relative risks of 5.44 and 4.15. These two districts accounted for 80 of the death certificates that were coded with this cause. In fact, only two other districts had relative risks greater than .5 (Beckley, with a risk of 1.23 and Denver with a risk of .82).

6. Accidents - Although the SMR for this cause for miners was high, the deaths seem to be distributed as expected among the different districts.

V. Summary of Major Findings

The major aim of this study has been to compare the long-term mortality experience of a cohort of coal miners covered by the United Mine Workers Health and Retirement Funds to that expected using the total United States male population as a control. The principal results are as follows:

1. The overall mortality of coal miners, as reflected by a Standardized Mortality Ratio of 101.6, is not excessively high when compared to the mortality of the total U.S. male population. Major causes of death revealing elevated risks are nonmalignant respiratory diseases, accidents, and stomach cancer.

2. Nonmalignant respiratory diseases with high Standardized Mortality Ratios include emphysema (143.7), asthma (174.9), and tuberculosis (145.5). Furthermore, all of the cases where bronchitis was the underlying cause of death also mentioned emphysema. An exact SMR could not be computed for pneumoconiosis, but even a conservative estimate would be very high. Pneumoconiosis was the underlying cause of death for 187 cases and a contributory cause in an additional 393 cases.

3. Mortality from all malignant neoplasms results in an SMR of 97.7. Respiratory cancer has an SMR of 112.5, which is intermediate to what has been reported in previous studies of U.S. coal miners. With this amount of excess, one must be cautious when attributing it to occupational exposure since it is well within the range of what could result from differences in smoking or geographic regions between the study and control populations.

The SMR for stomach cancer was 134.9 and the finding of an excess for this cause is consistent with previous studies.

4. The SMR for all cardiovascular diseases is 95.2. No significantly high excess is noted for any subcategory of cardiovascular disease.

5. Although there was not a large difference between the pensioner group and the nonpensioner group in the SMR for all causes (106.1 and 98.3, respectively) the SMR for some causes of death differed for the two subgroups. The SMR for stomach cancer was 151.2 for the pensioner group and 111.4 for nonpensioners. For accidents, the SMR was higher in the nonpensioned group (181.0 compared to 83.4).

6. The SMR for accidents for the nonpensioned group is 181.0. When deaths from accidents occurring within the mine were eliminated, the SMR is reduced to 93.0.

7. The relative number of times a cause of death appeared on death certificates as an underlying cause as opposed to a contributory cause is found to be consistent with other multiple cause of death studies. The major exception to this is diabetes which appears a larger proportion of times as a contributory cause for coal miners than for the other populations. This is of particular interest since the SMR for diabetes is low for coal miners (SMR = 58.1).

8. Although internal comparisons were made among different geographic regions, conclusions are difficult to make since, in most cases, it is impossible to determine whether differences in mortality patterns are due to differences in the coal mining populations or just a reflection of different mortality patterns for the total populations. One exception is

pneumoconiosis since it is primarily an occupational disease. When compared to the other districts, the Johnstown district (Central Pennsylvania) showed a relative risk of 4.22 ($P < .01$).

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Appendix I

Comparability Ratios for Conversion from 7th to 8th Revision

Category numbers according to the Eighth Revision, 1967	Category numbers according to the Seventh Revision, 1955	Provisional comparability ratio[1]
008, 009	571, 764	1.185
010-019	001-019	0.950
090-097	020-029	0.322
Remainder of 000-136	030-138	0.983
140-209	140-205	0.988
140-149	140-148	1.055
150-159	150-156A, 157-159	0.938
160-163	160-164	1.024
174	170	0.991
180-187	171-179	0.999
188, 189	180, 181	1.013
170-173, 190-199	156B, 165, 190-199	1.000
204-207	204	0.998
200-203, 208, 209	200-203, 205	1.056
210-239	210-239	0.968
250	260	0.994
280-285	290-293	0.944
320	340	0.959
390-448	330-334, 400-456	0.999
390-398, 402, 404, 410-429	400-443	1.000
390-398	400-402, 410-416	1.138
402, 404	440, 441, 442, 443	0.398
410-414	420, 422.1	1.063
424, 428	421, 422.0, 422.2	0.828
420-423, 425-427, 429	430-434	0.801
400, 401, 403	444-447	0.820
430-438	330334	0.981
440	450	0.894
441-448	451-456	1.549
466	500	1.195
470-474, 480-486	480-483, 490-493, 763	0.993
470-474	480-483	0.960
480-486	490-493, 763	0.994
490-493	501, 502, 527.1, 241	0.994
490+491	501, 502	1.068
492	527.1	1.049
493	241	0.696
531-533	540, 541	0.979

Comparability Ratios for Conversion from 7th to 8th Revision

Category numbers according to the Eighth Revision, 1967	Category numbers according to the Seventh Revision, 1955	Provisional comparability ratio[1]
550-553, 560	560, 561, 570	0.757
571	581	1.003
574, 575	584, 585	0.982
580-584	590-594	0.880
590	600	1.026
600	610	0.904
740-759	750-759	1.008
760-769.2, 769.4-772, 77-778	760-762, 765-776	0.968
780-796	780-795	0.994
Residual	By subtraction:	0.940
E800-E949	E800-E962	0.926
E810-E823	E810-E835	0.974
E800-E807, E825-E949	E800-E802, E840-E962	0.884
E950-E959	E963, E970-E979	0.939
E960-E978	E964, E980-E985	0.993
E980-E999	--	--
E980-E989	--	--
E990-E999	E990-E999, E965	0.919

[1] Ratio of deaths assigned according to the Eighth Revision to deaths assigned according to the Seventh Revision.

Rules for Coding Multiple Cause for Coal Miners

1. Use 7th revision ICD - 4 digit codes (001 - E999) excluding Symptoms, Senility, and Ill-defined conditions (780-795), Female Disorder Codes (620-626, 630-637), Deliveries and Complications of Pregnancy, Childbirth, and Puerperium (640-689), Diseases of Early Infancy (760-776).

2. Code the underlying cause on line A.

3. Under the category 260X (Diabetes) some resulting conditions may be coded back to 260X. Be sure to code the associated cause as indexed as if it were without diabetes. i.e.:

   Diabetic retinitis is coded to 260X. For this study code 260X (Diabetes) and code 377X (Retinitis) also.
   Diabetic nephrosis is coded to 260X. Code 260X (Diabetes) and 591X (Nephrosis).

4. Do not use Psychosis with cerebral arteriosclerosis (360X) as an underlying cause, but do use it if given as associated cause. i.e.:

   a. Ca. of lung (163X)
   b. Psychosis due to (309X)
   c. Cerebral arteriosclerosis (334X)

   Code underlying cause 163X and the associated cause 306X.

   The same rule would apply to Psychosis of Other Demonstrable Etiology (308X). In other words, where psychosis is stated as due to a condition that can be coded to the combined code, use it rather than 2 separate codes.

5. In the case of a vague term modified or later clarified by a more specific term, do not code the vague term. i.e.:

   a. Retroperitoneal tumor (230X)
   b. Malignant Schwannoma (158X)
   c. ----------

   Code only 158X

a. Lymphosarcoma (2001)
b.
c.

Major findings of operation.
Reticulum - sarcoma caecum (2000)
Code 2000

6. Assume the terms carcinomatosis, generalized carcinoma, etc. with a primary cancer to be the same as metastasis, and code it to 1999, as an associated cause.

7. Do not code hemorrhage or obstruction of a site or system when a cancer or its metastasis is involved in this particular site or system. i.e.:

a. Intestinal hemorrhage
b. Metastasis from
c. Carcinoma upper left lobe of lung
Code - 163X (underlying)
1999 (metastasis)

8. Do not code hemorrhages from leukemia no matter what sites are hemorrhaging.

Do not code malnutrition, septaecemia or secondary anemia with a cancer.

9. Do not code an operation or the findings of an operation performed for a disease condition already coded.

Do not code any condition due to a treatment for an already existing and coded disease unless the resulting condition actually caused the death. i.e.:

a.	Bronchopneumonia	4 wks.
b.	Adenocarcinoma bronchogenic	1 yr.
c.	Dermatitis due to radiation	6 mo.

Do not code the Radiation dermatitis.

10. Do not code an accident cause if it is the direct result of a disease condition. i.e.:

a.	Strangulation	5 min.
b.	Pulmonary congestion	1 wk.
c.	Disseminated miliary tuberculosis	

Code underlying 0192 and associated cause 522X.

11. Do not code atelectasis with a lung condition. i.e.:

a.	Malignancy of left lung	6 mos.
b.	Atelectasis massive	
c.		

Code only 163X

12. Pleural effusion (003) with a cancer will be coded to non-tubercular pleural effusion (5192), unless tuberculosis is present on the certificate.

13. For the combined terms Arteriosclerotic hypertensive heart disease and Hypertensive arteriosclerotic heart disease, code both 4200 and 443X.

14. The special code 434.5 was used for cor pulmonale. The special code 910A was used for a mine disaster.

15. Whenever a 4221 was coded, a 4500 was also coded since the .1 in 4221 implies arteriosclerosis.

Appendix II

UNDERLYING CAUSE OF DEATH FREQUENCY

TOTAL COAL MINERS

COD	FREQUENCY		
	TOTAL	WHITE	NONWHITE
1.0	24	19	4
2.0	1	1	0
2.1	34	24	9
2.2	1	1	0
8.0	1	1	0
16.0	1	1	0
19.2	1	0	1
22.0	8	7	0
23.0	5	2	3
26.0	3	3	0
53.0	1	1	0
53.4	7	6	1
72.1	1	1	0
132.0	2	1	1
134.1	1	0	1
134.3	1	1	0
140.9	2	2	0
141.9	4	3	0
142.0	1	1	0
143.0	1	0	0
144.0	6	6	0
145.0	5	4	1
145.9	1	1	0
146.8	3	3	0
147.0	1	1	0
148.0	7	7	0
150.0	27	25	1
151.0	127	118	2
152.7	2	2	0
152.9	1	1	0
153.8	4	4	0
153.1	2	1	1
153.2	2	2	0
153.3	16	16	0
153.8	54	47	6
153.9	8	7	0
154.0	39	36	3
155.0	8	8	0
155.1	17	17	0
156.0	1	1	0
156.1	16	15	1
156.2	6	4	2
157.0	74	70	4
158.0	2	2	0
159.0	2	2	0
160.2	1	1	0
160.9	1	1	0
161.0	19	14	5
162.0	1	1	0
162.1	130	116	14

UNDERLYING CAUSE OF DEATH FREQUENCY

TOTAL COAL MINERS

COD	FREQUENCY		
	TOTAL	WHITE	NONWHITE
163.0	220	199	18
163.4	1	1	0
165.0	8	7	0
177.0	122	100	18
179.0	2	2	0
180.0	24	20	2
181.0	42	38	3
190.9	3	3	0
191.0	1	1	0
191.3	2	2	0
191.7	1	1	0
191.9	2	2	0
193.0	14	14	0
193.2	1	1	0
193.9	2	2	0
194.0	1	0	0
195.0	2	2	0
196.0	3	3	0
196.7	1	1	0
196.9	3	2	1
197.9	2	1	1
199.0	1	1	0
199.1	7	7	0
199.2	59	53	4
200.0	11	10	0
200.1	20	19	0
200.2	4	4	0
201.0	11	10	0
202.1	2	2	0
203.0	10	8	2
204.0	21	20	1
204.1	7	7	0
204.2	2	2	0
204.3	15	12	2
204.4	5	5	0
223.0	3	2	1
227.0	1	1	0
230.0	1	1	0
231.0	1	1	0
237.0	8	4	1
241.0	32	30	0
250.0	1	1	0
252.0	1	1	0
253.0	2	1	1
260.0	64	51	12
274.0	3	3	0
286.5	5	4	0
287.0	1	1	0
288.0	1	1	0
292.2	1	0	0

UNDERLYING CAUSE OF DEATH FREQUENCY

TOTAL COAL MINERS

COD	FREQUENCY		
	TOTAL	WHITE	NONWHITE
292.3	1	1	0
292.4	1	0	1
294.0	1	1	0
296.0	1	1	0
307.0	2	2	0
309.0	4	3	1
322.0	4	4	0
322.1	1	1	0
322.2	1	1	0
330.0	23	22	1
331.0	440	378	37
332.0	267	220	32
332.1	1	1	0
334.0	71	65	6
340.0	1	0	1
340.2	1	1	0
340.3	1	1	0
342.6	1	0	1
343.0	2	2	0
345.0	3	3	0
350.0	7	6	0
352.0	6	6	0
353.3	2	1	1
355.0	4	4	0
356.1	7	7	0
388.0	1	0	1
401.0	1	1	0
401.1	1	1	0
410.0	9	8	0
411.0	9	7	1
414.0	2	2	0
416.0	13	10	1
420.0	729	637	61
420.1	1944	1783	104
421.1	7	7	0
421.3	2	1	1
421.4	6	6	0
422.1	150	130	15
422.2	23	20	2
430.0	2	1	1
431.0	2	2	0
433.0	28	25	2
433.1	15	14	1
434.1	39	31	7
434.2	1	1	0
434.4	42	39	3
434.5	4	3	1
442.0	50	43	7
442.4	1	0	0
443.0	162	121	38

UNDERLYING CAUSE OF DEATH FREQUENCY

TOTAL COAL MINERS

COD	FREQUENCY		
	TOTAL	WHITE	NONWHITE
444.0	12	9	2
445.0	5	4	1
446.0	41	34	5
450.0	127	118	9
450.1	6	6	0
451.0	40	33	7
452.0	1	1	0
453.1	1	1	0
453.3	1	1	0
454.8	3	3	0
455.0	1	1	0
456.0	3	3	0
460.0	2	2	0
461.9	1	1	0
463.0	5	3	2
464.0	4	4	0
465.0	44	38	3
466.0	12	10	2
467.2	4	1	3
480.0	18	13	3
481.0	10	10	0
490.0	34	27	6
491.0	122	110	12
492.0	23	20	2
493.0	38	31	5
500.0	1	0	1
502.0	22	18	3
502.1	4	4	0
518.0	1	1	0
519.0	1	1	0
520.0	2	2	0
521.0	4	3	0
522.0	3	3	0
522.4	1	1	0
523.0	62	53	8
523.1	39	33	2
523.3	83	76	4
524.0	3	3	0
525.0	58	50	6
526.0	11	11	0
527.0	1	1	0
527.1	170	151	16
527.2	30	26	4
539.1	3	3	0
540.0	18	16	2
540.1	6	5	0
541.0	12	12	0
541.1	6	6	0
542.0	1	1	0
542.1	2	1	0

UNDERLYING CAUSE OF DEATH FREQUENCY

TOTAL COAL MINERS

COD	FREQUENCY		
	TOTAL	WHITE	NONWHITE
543.0	1	1	0
544.2	1	0	1
545.0	1	1	0
550.1	5	5	0
560.4	1	1	0
560.5	2	2	0
561.0	1	0	0
561.3	1	1	0
561.5	1	0	0
570.2	16	15	1
570.3	1	1	0
570.4	1	1	0
570.5	14	13	0
571.1	6	6	0
572.1	6	6	0
572.2	2	2	0
572.0	15	13	0
580.0	1	1	0
581.0	47	41	3
581.1	17	14	2
583.0	2	2	0
584.0	9	9	0
585.0	13	13	0
586.0	6	6	0
587.0	11	10	0
590.0	4	4	0
591.0	1	1	0
592.0	25	23	2
593.0	12	11	1
600.0	27	24	2
600.1	1	0	1
600.2	1	1	0
602.0	5	5	0
603.0	3	3	0
605.0	1	1	0
606.0	1	1	0
609.0	6	5	1
610.0	18	15	2
611.0	1	1	0
612.0	1	1	0
693.2	1	1	0
784.1	1	0	1
710.0	1	1	0
715.0	3	3	0
722.0	3	3	0
922.1	1	0	0
725.0	1	1	0
730.2	1	0	0
733.0	1	1	0
744.1	1	1	0

UNDERLYING CAUSE OF DEATH FREQUENCY

TOTAL COAL MINERS

COD	FREQUENCY		
	TOTAL	WHITE	NONWHITE
753.1	1	1	0
756.2	2	2	0
757.1	2	2	0
757.3	1	0	1
759.8	1	0	1
782.4	13	12	1
782.9	1	1	0
783.1	2	2	0
785.6	1	1	0
792.0	4	3	1
794.0	4	4	0
795.0	4	3	1
795.2	2	2	0
795.4	56	40	15
795.5	75	53	11
802.0	4	3	1
810.0	1	0	1
810.4	1	1	0
812.0	1	1	0
812.4	12	10	1
812.9	1	1	0
814.4	1	1	0
814.7	1	0	1
815.4	1	1	0
816.0	1	1	0
816.1	8	8	0
816.4	18	16	1
819.4	1	1	0
819.9	1	1	0
821.4	1	1	0
823.0	3	3	0
823.4	9	9	0
824.0	2	2	0
824.4	1	1	0
825.0	2	1	1
825.4	21	18	3
825.5	1	1	0
825.9	1	1	0
850.0	4	4	0
851.2	1	1	0
880.9	1	1	0
882.8	1	0	1
888.1	1	1	0
888.9	2	2	0
890.9	1	0	1
891.0	1	1	0
892.9	1	1	0
894.2	2	2	0
895.0	1	1	0
900.0	10	8	0

UNDERLYING CAUSE OF DEATH FREQUENCY

TOTAL COAL MINERS

COD	FREQUENCY TOTAL	WHITE	NONWHITE
900.6	1	0	0
900.9	2	2	0
901.3	1	1	0
902.0	9	9	0
902.1	1	1	0
902.2	3	3	0
902.7	1	1	0
902.8	1	0	0
903.0	2	1	1
903.5	2	2	0
903.7	3	3	0
904.9	3	3	0
908.0	3	2	1
908.7	2	2	0
908.9	19	17	1
910.1	1	1	0
910.2	34	30	3
910.5	1	1	0
910.9	1	1	0
910.A *	69	0	0
911.4	12	11	0
912.1	6	6	0
912.2	12	12	0
912.3	2	2	0
912.9	1	1	0
913.0	1	1	0
914.2	7	7	0
914.3	1	1	0
914.7	1	1	0
914.A	2	2	0
916.0	19	15	3
916.2	6	6	0
916.3	1	1	0
916.7	1	1	0
916.9	3	3	0
919.0	5	5	0
919.1	1	1	0
919.2	1	1	0
919.9	5	5	0
921.9	1	1	0
923.9	2	2	0
925.2	2	2	0
925.3	1	1	0
927.0	1	1	0
929.5	1	1	0
929.8	9	5	4
929.9	1	1	0
932.9	1	1	0
933.9	1	1	0
936.0	1	1	0

UNDERLYING CAUSE OF DEATH FREQUENCY

TOTAL COAL MINERS

COD	FREQUENCY		
	TOTAL	WHITE	NONWHITE
936.1	1	1	0
936.2	6	6	0
936.9	8	5	2
950.0	1	1	0
953.0	1	1	0
962.0	5	5	0
970.2	1	1	0
971.1	1	1	0
971.6	1	1	0
973.1	3	3	0
974.0	8	8	0
975.0	1	1	0
976.	1	1	0
976.0	61	58	1
977.0	3	3	0
978.0	1	1	0
981.0	21	13	8
982.0	4	3	1
983.0	4	2	2
983.6	1	1	0

TABLE 1A

General Causes of Death for which Standardized Mortality Ratios were Computed

CAUSE OF DEATH	ICD CODE (Seventh Revision)
All Causes	1-999
All Malignant Neoplasms	140-205
Benign and Unspecified Neoplasms	210-239
Major Cardiovascular Diseases	330-334,400-456
Bronchitis	500-502
Acute Bronchitis and Bronchiolitis	500
Chronic and Unqualified Bronchitis	501-502
Influenza	480-483
Pneumonia	490-493
Emphysema	527.1
Asthma	241
Tuberculosis	1-19
Syphilis	20-29
Other Infective and Parasitic Diseases	30-138
Diabetes Mellitus	260
Peptic Ulcer	540-541
Cirrhosis of Liver	581
Cholelithiasis, Cholecystitis, and Cholangitis	584-585
Nephritis and Nephrosis	590-594
Accidents	800-962
Suicides	963,970-979
Homicides	964,980-985
Ill-Defined Causes	780-795
All Other Causes	Remainder

Appendix III

TABLE 1B

Causes of Death Due to Neoplasms for which Standardized Mortality Ratios were Computed

CAUSE OF DEATH (Neoplasms)	ICD CODE (Seventh Revision)
All Malignant Neoplasms	140-205
Buccal Cavity and Pharynx	140-148
Digestive Organs and Peritoneum	150-159
Respiratory Organs	160-164
Breast	170
Genital Organs	177-179
Urinary Organs	180-181
Leukemia and Aleukemia	204
Other Lymphatic and Hematopoietic	200-203,205
All Other Sites	165,190-199
Benign and Unspecified Neoplasms	210-239

Appendix III

TABLE 1C

Causes of Death Due to Cardiovascular Disease for which Standardized Mortality Ratios were Computed

CAUSE OF DEATH (Cardiovascular Diseases)	ICD CODE (Seventh Revision)
Major Cardiovascular Diseases	330-334,400-456
Active Rheumatic Fever and Chronic Rheumatic Heart Disease	400-402,410-416
Hypertensive Heart Disease	440-443
Ischemic Heart Disease	420,422.1
Chronic Disease of Endocardium and Other Myocardial Insufficiency	421,422.0,422.2
All Other Forms of Heart Disease	430-434
Hypertension	444-447
Cerebrovascular Disease	330-334
Arteriosclerosis	450
Other Diseases of Arteries, Arterioles, and Capillaries	451-456

TABLE 1

Causes of Death for which Ratios of Total/Primary were Computed in Multiple Causes of Death Analysis

CAUSE OF DEATH	ICD CODE (Seventh Revision)
All Causes	1-999
All Malignant Neoplasms	140-205
Digestive Organs and Peritoneum	150-159
Lung, Bronchus, Trachea	162-163
All Other Sites	Remainder (140-205)
Cardiovascular-Renal Disease	330-334,400-468,592-594
Vascular Lesions Affecting CNS	330-334
Arteriosclerotic and Degenerative Heart Disease	420-422
Hypertensive Heart Disease	440-443
Other Hypertensive Disease	444-447
General Arteriosclerosis	450
Chronic Nephritis	592-594
All Other Cardiovascular-Renal Disease	Remainder (330-334, 400-468,592-594)
Diabetes Mellitus	260
Nonmalignant Respiratory Disease	470-527
Upper Respiratory Infections and Influenza	470-483
Pneumonia	490-493
Bronchitis	500-502
Pneumoconiosis and Pulmonary Fibrosis of Occupational Origin	523-524
All Other Nonmalignant Respiratory Disease	Remainder (470-527)
Tuberculosis	1-19
Syphilis	20-29
Ulcer of Stomach	540
Cirrhosis of Liver	581
Accidents	800-962
Suicides	963,970-979
Homicides	964,980-985
All Other Causes	Remainder (1-999)

Appendix IV

Cause-Specific Frequencies of Primary and Total Causes of Death and Ratios of Total/Primary for Various Age Groups

Table 2

Cause-Specific Frequencies of Primary (Underlying) and Total (Primary and Contributory) Causes of Death and Ratios of Total/Primary for Coalminers, Ages 34 or Less, by Cause and by Race*

CAUSE OF DEATH	WHITE			NONWHITE			TOTAL		
	Primary	Total	Ratio*	Primary	Total	Ratio*	Primary	Total	Ratio*
All Causes	32	36	1.13	1	1	1.00	33	37	1.12
All Malignant Neoplasms	4	4	1.00	0	0	--	4	4	1.00
Digestive Organs and Peritoneum	0	0	--	0	0	--	0	0	--
Lung, Bronchus, Trachea	0	0	--	0	0	--	0	0	--
All Other Sites	4	4	1.00	0	0	--	4	4	1.00
Cardiovascular-Renal Disease	4	6	1.50	0	0	--	4	6	1.50
Vascular Lesions Affecting CNS	1	1	1.00	0	0	--	1	1	1.00
Arteriosclerotic & Degenerative Heart Disease	2	2	1.00	0	0	--	2	2	1.00
Hypertensive Heart Disease	0	0	--	0	0	--	0	0	--
Other Hypertensive Disease	0	0	--	0	0	--	0	0	--
General Arteriosclerosis	0	2	--	0	0	--	0	2	--
Chronic Nephritis	1	1	1.00	0	0	--	1	1	1.00
All Other Cardiovascular-Renal Disease	0	0	--	0	0	--	0	0	--
Diabetes Mellitus	0	0	--	0	0	--	0	0	--

* Ratio = Total/Primary

Appendix IV

Table 2 (Cont'd.)

CAUSE OF DEATH	WHITE			NONWHITE			TOTAL		
	Primary	Total	Ratio*	Primary	Total	Ratio*	Primary	Total	Ratio*
Nonmalignant Respiratory Disease	0	2	--	0	0	--	0	2	--
Upper Respiratory Infections and Influenza	0	0	--	0	0	--	0	0	--
Pneumonia	0	2	--	0	0	--	0	2	--
Bronchitis	0	0	--	0	0	--	0	0	--
Pneumoconiosis and Pulmonary Fibrosis of Occupational Origin	0	0	--	0	0	--	0	0	--
All Other Nonmalignant Respiratory Disease	0	0	--	0	0	--	0	0	--
Tuberculosis	0	0	--	0	0	--	0	0	--
Syphilis	0	0	--	0	0	--	0	0	--
Ulcer of Stomach	0	0	--	0	0	--	0	0	--
Cirrhosis of Liver	0	0	--	0	0	--	0	0	--
Accidents	17	17	1.00	0	0	--	17	17	1.00
Suicides	2	2	1.00	0	0	--	2	2	1.00
Homicides	3	3	1.00	0	0	--	3	3	1.00
All Other Causes	2	2	1.00	1	1	1.00	3	3	1.00

* Ratio = Total/Primary

Appendix IV

Table 3

Cause-Specific Frequencies of Primary (Underlying) and Total (Primary & Contributory) Causes of Death and Ratios of Total/Primary for Coalminers, Ages 35-44, by Cause and by Race

CAUSE OF DEATH	WHITE			NONWHITE			TOTAL		
	Primary	Total	Ratio*	Primary	Total	Ratio*	Primary	Total	Ratio*
All Causes	186	243	1.31	7	8	1.14	193	251	1.30
All Malignant Neoplasms	25	26	1.04	0	0	--	25	26	1.04
Digestive Organs and Peritoneum	8	8	1.00	0	0	--	8	8	1.00
Lung, Bronchus, Trachea	7	8	1.14	0	0	--	7	8	1.14
All Other Sites	10	10	1.00	0	0	--	10	10	1.00
Cardiovascular-Renal Disease	59	91	1.54	1	2	2.00	60	93	1.55
Vascular Lesions Affecting CNS	3	8	2.67	0	0	--	3	8	2.67
Arteriosclerotic & Degenerative Heart Disease	44	49	1.11	1	1	1.00	45	50	1.11
Hypertensive Heart Disease	0	1	--	0	1	--	0	2	--
Other Hypertensive Disease	0	2	--	0	0	--	0	2	--
General Arteriosclerosis	0	0	--	0	0	--	0	0	--
Chronic Nephritis	4	5	1.25	0	0	--	4	5	1.25
All Other Cardiovascular-Renal Disease	8	26	3.25	0	0	--	8	26	3.25
Diabetes Mellitus	1	1	1.00	0	0	--	1	1	1.00

* Ratio = Total/Primary

Table 3 (Cont'd.)

CAUSE OF DEATH	WHITE			NONWHITE			TOTAL		
	Primary	Total	Ratio*	Primary	Total	Ratio*	Primary	Total	Ratio*
Nonmalignant Respiratory Disease	8	18	2.25	1	1	1.00	9	19	2.11
Upper Respiratory Infections and Influenza	1	2	2.00	0	0	--	1	2	2.00
Pneumonia	3	6	2.00	1	1	1.00	4	7	1.75
Bronchitis	1	1	1.00	0	0	--	1	1	1.00
Pneumoconiosis and Pulmonary Fibrosis of Occupational Origin	2	3	1.50	0	0	--	2	3	1.50
All Other Nonmalignant Respiratory Disease	1	6	6.00	0	0	--	1	6	6.00
Tuberculosis	1	2	2.00	0	0	--	1	2	2.00
Syphilis	0	0	--	0	0	--	0	0	--
Ulcer of Stomach	0	0	--	0	0	--	0	0	--
Cirrhosis of Liver	1	2	2.00	0	0	--	1	2	2.00
Accidents	60	60	1.00	1	1	1.00	61	61	1.00
Suicides	15	15	1.00	0	0	--	15	15	1.00
Homicides	5	5	1.00	2	2	1.00	7	7	1.00
All Other Causes	11	23	2.09	2	2	1.00	13	25	1.92

* Ratio = Total/Primary

Appendix IV

Table 4

Frequencies of Primary and Total (Primary and Contributory) Causes of Death for Coalminers, Ages 45-54, by Cause and by Race

CAUSE OF DEATH	WHITE			NONWHITE			TOTAL		
	Primary	Total	Ratio*	Primary	Total	Ratio*	Primary	Total	Ratio*
All Causes	507	740	1.46	34	59	1.74	541	799	1.48
All Malignant Neoplasms	87	90	1.03	2	5	2.50	89	95	1.07
Digestive Organs and Peritoneum	17	19	1.12	0	0	--	17	19	1.12
Lung, Bronchus, Trachea	33	33	1.00	2	3	1.50	35	36	1.03
All Other Sites	37	38	1.03	0	2	--	37	40	1.08
Cardiovascular-Renal Disease	235	351	1.49	19	33	1.74	254	384	1.51
Vascular Lesions Affecting CNS	20	34	1.70	1	3	3.00	21	37	1.76
Arteriosclerotic & Degenerative Heart Disease	172	192	1.12	9	10	1.11	181	202	1.12
Hypertensive Heart Disease	8	15	1.88	2	2	1.00	10	17	1.70
Other Hypertensive Disease	6	12	2.00	1	2	2.00	7	14	2.00
General Arteriosclerosis	1	20	20.00	0	1	--	1	21	21.00
Chronic Nephritis	6	11	1.83	1	2	2.00	7	13	11.86
All Other Cardiovascular-Renal Disease	22	67	3.05	5	13	2.60	27	80	2.96
Diabetes Mellitus	4	7	1.75	0	0	--	4	7	1.75

* Ratio = Total/Primary

Appendix IV

Table 4 (Cont'd.)

CAUSE OF DEATH	WHITE			NONWHITE			TOTAL		
	Primary	Total	Ratio*	Primary	Total	Ratio*	Primary	Total	Ratio*
Nonmalignant Respiratory Disease	27	83	3.07	4	10	2.50	31	93	3.00
Upper Respiratory Infections and Influenza	0	0	--	0	0	--	0	0	---
Pneumonia	10	16	1.60	0	1	--	10	17	1.70
Bronchitis	1	2	2.00	0	0	--	1	2	2.00
Pneumoconiosis and Pulmonary Fibrosis of Occupational Origin	8	23	2.88	1	1	1.00	9	24	2.67
All Other Nonmalignant Respiratory Disease	8	42	5.25	3	8	2.67	11	50	4.55
Tuberculosis	6	7	1.17	2	3	1.50	8	10	1.25
Syphilis	1	1	1.00	0	0	--	1	1	1.00
Ulcer of Stomach	3	4	1.33	0	0	--	3	4	1.33
Cirrhosis of Liver	7	12	1.71	0	0	--	7	12	1.71
Accidents	71	73	1.03	2	2	1.00	73	75	1.03
Suicides	13	13	1.00	0	0	--	13	13	1.00
Homicides	4	4	1.00	2	2	1.00	6	6	1.00
All Other Causes	49	95	1.94	3	4	1.33	52	99	1.90

* Ratio = Total/Primary

Appendix IV

Table 5

Frequencies of Primary and Total (Primary and Contributory) Causes of Death for Coalminers, Ages 55-64, by Cause and by Race

CAUSE OF DEATH	WHITE			NONWHITE			TOTAL		
	Primary	Total	Ratio*	Primary	Total	Ratio*	Primary	Total	Ratio*
All Causes	1039	1835	1.77	133	247	1.86	1172	2082	1.78
All Malignant Neoplasms	209	233	1.11	13	15	1.15	222	248	1.12
Digestive Organs and Peritoneum	63	72	1.14	3	3	1.00	66	75	1.14
Lung, Bronchus, Trachea	93	97	1.04	7	8	1.14	100	105	1.05
All Other Sites	53	64	1.21	3	4	1.33	56	68	1.21
Cardiovascular-Renal Disease	539	949	1.76	69	139	2.01	608	1088	1.79
Vascular Lesions Affecting CNS	71	123	1.73	16	30	1.88	87	153	1.76
Arteriosclerotic & Degenerative Heart Disease	389	474	1.22	26	39	1.50	415	513	1.24
Hypertensive Heart Disease	23	47	2.04	14	16	1.14	37	63	1.70
Other Hypertensive Disease	3	28	9.33	2	10	5.00	5	38	7.60
General Arteriosclerosis	6	80	13.33	3	13	4.33	9	93	10.33
Chronic Nephritis	2	6	3.00	2	4	2.00	4	10	2.50
All Other Cardiovascular-Renal Disease	45	191	4.24	6	27	4.50	51	218	4.27
Diabetes Mellitus	3	30	10.00	2	4	2.00	5	34	6.80

* Ratio = Total/Primary

Appendix IV

Table 5 (Cont'd.)

CAUSE OF DEATH	WHITE			NONWHITE			TOTAL		
	Primary	Total	Ratio*	Primary	Total	Ratio*	Primary	Total	Ratio*
Nonmalignant Respiratory Disease	122	346	2.84	14	39	2.79	136	385	2.83
Upper Respiratory Infections and Influenza	2	3	1.50	0	0	--	2	3	1.50
Pneumonia	10	33	3.30	6	8	1.33	16	41	2.56
Bronchitis	4	13	3.25	1	2	2.00	5	15	3.00
Pneumoconiosis and Pulmonary Fibrosis of Occupational Origin	44	110	2.50	2	10	5.00	46	120	2.61
All Other Nonmalignant Respiratory Disease	62	187	3.02	5	19	3.80	67	206	3.07
Tuberculosis	17	24	1.41	3	3	1.00	20	27	1.35
Syphilis	5	5	1.00	0	0	--	5	5	1.00
Ulcer of Stomach	3	8	2.67	0	0	--	3	8	2.67
Cirrhosis of Liver	10	20	2.00	1	1	1.00	11	21	1.91
Accidents	49	57	1.16	13	14	1.08	62	71	1.15
Suicides	14	14	1.00	0	0	--	14	14	1.00
Homicides	2	2	1.00	3	3	1.00	5	5	1.00
All Other Causes	66	147	2.23	15	29	1.93	81	176	2.17

* Ratio = Total/Primary

Appendix IV

Table 6

Frequencies of Primary and Total (Primary and Contributory) Causes of Death for Coalminers, Ages 65 or More, by Cause and by Race

CAUSE OF DEATH	WHITE			NONWHITE			TOTAL		
	Primary	Total	Ratio*	Primary	Total	Ratio*	Primary	Total	Ratio*
All Causes	4896	10,132	2.07	471	972	2.06	5367	11,104	2.07
All Malignant Neoplasms	774	906	1.17	77	92	1.19	851	998	1.17
Digestive Organs and Peritoneum	288	317	1.10	17	21	1.24	305	338	1.11
Lung, Bronchus, Trachea	184	203	1.10	23	23	1.00	207	226	1.09
All Other Sites	302	386	1.28	37	48	1.30	339	434	1.28
Cardiovascular-Renal Disease	3052	6,089	2.00	267	554	2.07	3319	6,643	2.00
Vascular Lesions Affecting CNS	597	1,083	1.81	57	103	1.81	654	1,186	1.81
Arteriosclerotic & Degenerative Heart Disease	1977	2,593	1.31	147	194	1.32	2124	2,787	1.31
Hypertensive Heart Disease	133	242	1.82	29	45	1.55	162	287	1.77
Other Hypertensive Disease	38	162	4.26	5	22	4.40	43	184	4.28
General Arteriosclerosis	114	949	8.32	6	81	13.50	120	1,030	8.58
Chronic Nephritis	21	61	2.90	0	2	--	21	63	3.00
All Other Cardiovascular-Renal Disease	172	999	5.81	23	107	4.65	195	1,106	5.67
Diabetes Mellitus	43	209	4.86	10	23	2.30	53	232	4.38

* Ratio = Total/Primary

Appendix IV

Table 6 (Cont'd.)

CAUSE OF DEATH	WHITE			NONWHITE			TOTAL		
	Primary	Total	Ratio*	Primary	Total	Ratio*	Primary	Total	Ratio*
Nonmalignant Respiratory Disease	493	1,586	3.22	53	171	3.23	546	1,757	3.22
Upper Respiratory Infections and Influenza	22	28	1.27	3	3	1.00	25	31	1.24
Pneumonia	165	378	2.29	18	35	1.94	183	413	2.26
Bronchitis	16	70	4.38	3	9	3.00	19	79	4.16
Pneumoconiosis and Pulmonary Fibrosis of Occupational Origin	111	368	3.32	11	46	4.18	122	414	3.39
All Other Nonmalignant Respiratory Disease	179	742	4.15	18	78	4.33	197	820	4.16
Tuberculosis	23	60	2.61	9	14	1.56	32	74	2.31
Syphilis	6	15	2.50	3	4	1.33	9	19	2.11
Ulcer of Stomach	15	31	2.07	2	5	2.50	17	36	2.12
Cirrhosis of Liver	37	65	1.76	4	6	1.50	41	71	1.73
Accidents	105	156	1.49	10	12	1.20	115	168	1.46
Suicides	34	34	1.00	1	1	1.00	35	35	1.00
Homicides	5	5	1.00	4	4	1.00	9	9	1.00
All Other Causes	309	976	3.16	31	86	2.77	340	1,062	3.12

* Ratio = Total/Primary

TABLE 1

Approximate Geographic Locations for the Districts Served by Each Area Medical Office

Beckley	Southeast part of West Virginia
Birmingham	Alabama
Charleston	Southwestern part of West Virginia
Denver	Washington, Montana, Wyoming, Utah, Colorado, New Mexico, Alaska
Louisville*	Western Kentucky, Western Indiana and one part of Eastern Kentucky
Johnstown	Central Pennsylvania
Knoxville	Tennessee, part of Southeastern Kentucky
Morgantown	Northern part of West Virginia, Western Maryland, Southwest corner of Pennsylvania
Pittsburgh	Ohio and Western Pennsylvania
St. Louis	Iowa, Illinois, Missouri, Kansas, Oklahoma, Arkansas

* Later came under the jurisdiction of Evansville

TABLE 2A

General Causes of Death for which Relative Risks were Computed for Analysis by District

CAUSE OF DEATH	ICD CODE (Seventh Revision)
All Causes	1-999
All Malignant Neoplasms	140-205
Benign and Unspecified Neoplasms	210-239
Major Cardiovascular Diseases	330-334,400-456
Nonmalignant Respiratory Diseases	470-527
Influenza	480-483
Pneumonia	490-493
Bronchitis	500-502
Pneumoconiosis	523
Emphysema	527.1
All Other Nonmalignant Respiratory Diseases	Remainder (470-527)
Asthma	241
Tuberculosis of Respiratory System	1-8
Tuberculosis, other forms	10-19
Syphilis	20-29
Other Infective and Parasitic Diseases	30-138
Diabetes Mellitus	260
Peptic Ulcer	540-541
Cirrhosis of Liver	581
Cholelithiasis, Cholecystitis, and Cholangitis	584-585
Nephritis and Nephrosis	590-594
Accidents	800-962
Suicides	963,970-979
Homicides	964,980-985
Ill-Defined Causes	780-795
All Other Causes	Remainder

TABLE 2B

Causes of Death Due to Neoplasms for which Relative Risks were Computed for Analysis by District

CAUSE OF DEATH (Neoplasms)	ICD CODE (Seventh Revision)
All Malignant Neoplasms	140-205
Buccal Cavity and Pharynx	140-148
Digestive Organs and Peritoneum	150-159
Stomach	151
Large Intestine	153
Other Digestive and Peritoneal Organs	150,152,154-159
Respiratory Organs	160-164
Genital Organs	177-179
Urinary Organs	180-181
Leukemia and Aleukemia	204
Other Lymphatic and Hematopoietic	200-203,205
Other Sites	165,170,190-199
Brain	193
All Other Sites	165,170,190-192, 194-199
Benign and Unspecified Neoplasms	210-239

TABLE 2C

Causes of Death Due to Cardiovascular Disease
for which Relative Risks were Computed
for Analysis by District

CAUSE OF DEATH (Cardiovascular Diseases)	ICD CODE (Seventh Revision)
Major Cardiovascular Diseases	330-334,400-456
Active Rheumatic Fever and Chronic Rheumatic Heart Disease	400-402,410-416
Hypertensive Heart Disease	440-443
Ischemic Heart Disease	420,422.1
Chronic Disease of Endocardium and Other Myocardial Insufficiency	421,422.0,422.2
All Other Forms of Heart Disease	430-434
Hypertension	444-447
Cerebrovascular Disease	330-334
Arteriosclerosis	450
Other Diseases of Arteries, Arterioles, and Capillaries	451-456

Appendix V

Relative Risks for Selected Causes of Death
for each Medical Area

Table 3

CAUSE OF DEATH: All Causes

DISTRICT	Observed Deaths	Expected Deaths	Relative Risk [1]
Beckley	955	890.0	1.10**
Birmingham	350	340.0	1.04
Charleston	691	655.6	1.08
Denver	290	351.1	.80**
Evansville	466	421.6	1.15*
Johnstown	878	813.7	1.13**
Knoxville	938	1050.6	.85**
Morgantown	939	996.3	.91*
Pittsburgh	1351	1330.3	1.03
St. Louis	764	776.6	.98

1. Significance of Relative Risk based on Summary Chi-Square with one degree of freedom.

* Significant at 5% level.

** Significant at 1% level.

Appendix V

Table 4

CAUSE OF DEATH: All Cancers

DISTRICT	Observed Deaths	Expected Deaths	Relative Risk [1]
Beckley	147	145.1	1.02
Birmingham	42	55.5	.74
Charleston	132	105.8	1.30**
Denver	40	55.5	.70*
Evansville	59	68.0	.86
Johnstown	127	129.4	.98
Knoxville	152	170.5	.87
Morgantown	143	159.8	.88
Pittsburgh	257	209.7	1.30**
St. Louis	124	123.2	1.01

1. Significance of Relative Risk based on Summary Chi-Square with one degree of freedom.

* Significant at 5% level.

** Significant at 1% level.

Table 5

CAUSE OF DEATH: Digestive Cancers

DISTRICT	Observed Deaths	Expected Deaths	Relative Risk [1]
Beckley	43	47.2	.90
Birmingham	13	18.2	.70
Charleston	34	34.2	1.00
Denver	14	18.9	.73
Evansville	24	22.8	1.06
Johnstown	55	43.7	1.30
Knoxville	38	55.6	.65
Morgantown	51	53.6	.94
Pittsburgh	98	71.6	1.50**
St. Louis	38	42.1	.89

1. Significance of Relative Risk based on Summary Chi-Square with one degree of freedom.

* Significant at 5% level.

** Significant at 1% level.

Table 6

CAUSE OF DEATH: Respiratory Cancer

DISTRICT	Observed Deaths	Expected Deaths	Relative Risk [1]
Beckley	50	46.5	1.09
Birmingham	14	17.6	.79
Charleston	54	33.7	1.72**
Denver	10	16.4	.60
Evansville	13	20.7	.61
Johnstown	22	38.5	.54**
Knoxville	52	54.3	.95
Morgantown	46	48.5	.94
Pittsburgh	69	60.8	1.20
St. Louis	43	36.1	1.22

1. Significance of Relative Risk based on Summary Chi-Square with one degree of freedom.

* Significant at 5% level.

** Significant at 1% level.

Appendix V

Table 7

CAUSE OF DEATH: Cardiovascular Disease

DISTRICT	Observed Deaths	Expected Deaths	Relative Risk [1]
Beckley	515	483.7	1.09
Birmingham	185	187.2	.99
Charleston	320	350.1	.89
Denver	150	201.8	.70**
Evansville	284	238.1	1.25**
Johnstown	496	465.5	1.09
Knoxville	495	570.9	.83**
Morgantown	563	564.7	1.00
Pittsburgh	795	770.9	1.05
St. Louis	477	450.6	1.08

1. Significance of Relative Risk based on Summary Chi-Square with one degree of freedom.

* Significant at 5% level.

** Significant at 1% level.

Table 8

CAUSE OF DEATH: Nonmalignant Respiratory Diseases

DISTRICT	Observed Deaths	Expected Deaths	Relative Risk [1]
Beckley	118	85.9	1.47**
Birmingham	29	33.2	.87
Charleston	72	62.0	1.20
Denver	38	34.5	1.11
Evansville	41	41.1	1.00
Johnstown	116	79.2	1.57**
Knoxville	105	101.6	1.04
Morgantown	65	97.5	.63**
Pittsburgh	104	129.5	.76*
St. Louis	53	76.4	.66**

1. Significance of Relative Risk based on Summary Chi-Square with one degree of freedom.

* Significant at 5% level.

** Significant at 1% level.

Appendix V

Table 9

CAUSE OF DEATH: Pneumoconiosis

DISTRICT	Observed Deaths	Expected Deaths	Relative Risk [1]
Beckley	34	22.5	1.64*
Birmingham	9	8.6	1.05
Charleston	12	16.3	.71
Denver	6	8.2	.72
Evansville	1	10.2	.10**
Johnstown	60	19.1	4.22**
Knoxville	19	26.5	.68
Morgantown	10	24.0	.38**
Pittsburgh	28	30.4	.91
St. Louis	5	18.1	.26**

1. Significance of Relative Risk based on Summary Chi-Square with one degree of freedom.

* Significant at 5% level.

** Significant at 1% level.

Table 10

CAUSE OF DEATH: Emphysema Without Mention of Bronchitis

DISTRICT	Observed Deaths	Expected Deaths	Relative Risk [1]
Beckley	36	20.2	2.03**
Birmingham	7	7.8	.89
Charleston	18	14.2	1.30
Denver	14	7.8	1.90*
Evansville	14	9.5	1.53
Johnstown	14	17.8	.76
Knoxville	23	24.0	.95
Morgantown	13	22.5	.54*
Pittsburgh	23	28.8	.76
St. Louis	8	17.3	.43*

1. Significance of Relative Risk based on Summary Chi-Square with one degree of freedom.

* Significant at 5% level.

** Significant at 1% level.

Appendix V

Table 11

CAUSE OF DEATH: Accidents

DISTRICT	Observed Deaths	Expected Deaths	Relative Risk [1]
Beckley	52	57.7	.89
Birmingham	19	19.5	.98
Charleston	53	49.3	1.10
Denver	20	16.0	1.27
Evansville	30	21.0	1.47
Johnstown	31	38.1	.80
Knoxville	72	69.0	1.10
Morgantown	57	49.0	1.20
Pittsburgh	43	57.0	.72
St. Louis	30	31.5	.95

1. Significance of Relative Risk based on Summary Chi-Square with one degree of freedom.

* Significant at 5% level.

** Significant at 1% level.

Table 12

CAUSE OF DEATH: Ill-Defined Causes

DISTRICT	Observed Deaths	Expected Deaths	Relative Risk [1]
Beckley	26	19.7	1.39
Birmingham	33	7.4	5.44**
Charleston	47	14.9	4.15**
Denver	6	7.5	.32
Evansville	2	8.8	.22*
Johnstown	5	17.0	.27**
Knoxville	12	23.2	.48*
Morgantown	8	20.8	.35**
Pittsburgh	15	27.2	.50*
St. Louis	8	15.7	.48

1. Significance of Relative Risk based on Summary Chi-Square with one degree of freedom.

* Significant at 5% level.

** Significant at 1% level.