PNEUMOCONIOSIS IN APPALACHIAN BITUMINOUS COAL MINERS

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FOREWORD

Since the early part of the 20th century, the Public Health Service has been concerned with occupational health problems in the mining industry. The study reported in this publication is one of many conducted by the Public Health Service, in cooperation with the Bureau of Mines, relating to dust diseases of miners.

Although early studies in the United States had not indicated a major problem attributable to bituminous coal mine dust, investigators in the United Kingdom and Europe became aware of a potential disease problem in bituminous miners in the 1930's. Postwar studies confirmed a high prevalence of a dust disease identified as coal workers' pneumoconiosis. In 1952, evidence pointed toward a similar disease entity among bituminous miners in the United States. The study covered in this report was initiated in 1963 and was limited to investigation of the prevalence of pneumoconiosis in working and nonworking bituminous coal miners. It includes analyses of such factors as age and years underground in the development of roentgenographic evidence of pneumoconiosis and their relation to pulmonary symptoms, ventilatory function, and work capacity. Community studies were included to ascertain the frequency of similar symptoms and relationships in a nonmining population.

This study outlines the nature and extent of the problem of pneumoconiosis in Appalachian bituminous coal miners. While it provides information necessary to a better understanding of the problem, it must be followed by other investigations relating to the epidemiology, etiology, and prevention of pneumoconiosis in coal miners. Some of these studies are currently underway at the Environmental Control Administration's Appalachian Center for Environmental Health, Morgantown, W. Va.

The major shortcoming of this study was the lack of environmental data relating to dust, i.e., concentration or mass, particle size, and chemical composition. Such data will ultimately be necessary to determine more precisely the full impact of the work environment on pulmonary disease and impairment. Environmental studies towards fulfilling this need are presently underway as part of a cooperative effort between the Consumer Protection and Environmental Health Service and the Bureau of Mines.

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HENRY N. DOYLE

INTRODUCTION

Despite frequent warnings in the medical literature, pneumoconiosis in bituminous coal workers was not recognized as a specific disease entity until about 1936 when the Medical Research Council of Great Britain initiated a series of studies relating to the epidemiology, pathology, and roentgenography of chest diseases in coal miners. A great resurgence of interest in the disease occurred following World War II in Great Britain and other countries on the European continent. The work of many investigators proved that the disease was prevalent in practically all of the coal mining areas of the United Kingdom and Western Europe and that the disease was accounting for a great amount of disability among underground workers. Because the disease was not recognized in American workers until much later, most of our present knowledge is based on the work of investigators in the United Kingdom and Europe.

The study described in this report was among the first of the American investigations to be directed toward the epidemiology of the disease, although its primary objective was to determine the prevalence of chest diseases in the bituminous coal workers in the Appalachian area.

COAL MINERS' PNEUMOCONIOSIS—A SUMMARY OF PRESENT KNOWLEDGE

Considerable knowledge concerning coal miners' pneumoconiosis has been accumulated through the efforts of many investigators. The following summary is based largely on reports of British and European investigators. On some points, where total agreement between investigators was not possible and where disagreements exist, the conclusions are generally based on prevailing opinion.[1, 2]

1. Coal pneumoconiosis is a distinct clinical entity that results from inhalation of coal mine dust. The clinical diagnosis is based on roentgenographic evidence of nodulation together with a history of long-term exposure to coal dust. Coal pneumoconiosis is classified into two forms: simple pneumoconiosis and complicated pneumoconiosis. The latter classification is frequently referred to as progressive massive fibrosis. Some investigators recognize a third form: pneumoconiosis associated with rheumatoid arthritis.[3]

2. Classic descriptions of the pathology of coal workers' pneumoconiosis have been provided by Gough[4] and Heppleston.[5] Gough[4] stated:

> "Simple pneumoconiosis of coal workers is a focal disease but is different from classic silicosis."

He then described the basic lesion in simple pneumoconiosis:

> "It is seen as black spots throughout the lungs from microscopic size up to 5 mm. in diameter. These may be soft and indistinguishable by feel from the surrounding lung or may be hard and felt as nodules, depending on the amount of fibrosis. The latter is less dense than in silicotic nodules and may consist only of loose reticulum. When collagen is present it is rarely of concentric arrangement. In relation to both the soft and the hard foci the air spaces become dilated, giving a honeycomb appearance with the spaces 1 to 5 mm. in diameter. These black areas of focal emphysema constitute the characteristic feature of the disease."

Heppleston[5] gave the following description:

> "The principal change in the early stage of the simple pneumoconiosis of these coal workers, irrespective of the duration of their employment, the type of coal mined, or whether they had worked mainly at the coal face or not, consisted of a small aggregation of dust, 1 to 2 mm. in diameter, mostly contained in phagocytes and located in the region of the divisions of the respiratory bronchioles and their ac-

companying arterioles. The dust lay partly in the interstitial tissue at these points and partly in the surrounding alveoli and alveolar walls. The only other demonstrable structure in the macular lesion was a delicate network of reticulin fibers lying amongst the interstitial dust. The air passages, apart from occasional dust cells in their lumens, were normal. A little dust also tended to accumulate around some of the venules situated at the periphery of primary lung lobules and beneath the pleura, especially where it was joined by the fibrous septa delineating the secondary lobules of the lung: in these situations, however, dust was relatively insignificant in amount. No evidence of a linear collection of dust along the course of the peribronchial and periarterial lymphatic vessels could be found, although some pigment had been carried to the hilar lymph glands, and a little occurred in tiny foci where bronchi or nonrespiratory bronchioles divided. At this early stage of the disease, the vesicles around the main dust foci showed no evidence of emphysema, and there was no general distortion of the elastic fiber network of the lung, but elastic fibers were absent from the interstitial accumulations of dust.

"In only a few cases were these small lesions present in relation to respiratory bronchioles, most specimens showing larger dust foci, measuring 2 to 4 mm. across, in the same locations. In effect the larger lesions represented well-defined areas of consolidation, some of which were apparently still in process of formation and will therefore be described as formative lesions, while other macules were shrunken, so that they may be referred to as retrogressive lesions. In formative lesions the original pulmonary structure was not completely obscured, since alveolar walls heavily infiltrated with dust phagocytes and air spaces packed with similar cells could be seen in the body of such lesions. At the margins of formative macules dust cells extended for a short distance into the alveolar walls and collected in the spaces abutting on the lesions. Most of the phagocytes were, however, in close apposition and enmeshed by irregularly disposed reticulin fibers, the staining properties of which suggested that in parts a transformation to fine collagenous connective tissue was taking place. Fragmented elastic fibers could be detected at the edges of some of the formative lesions. The surrounding lung tissue, at this stage, showed no abnormality with regard either to the size of the air spaces or to the fibrous components, reticulin or elastic, of the alveolar walls. Only occasionally were dust cells found lying free in the alveoli throughout the lung. In some lungs the macular lesions, while remaining quite discrete, showed features of retrogression which may be taken to indicate a later stage in the evolution of simple pneumoconiosis. The focal lesions were now shrunken and very compact, with no trace of vesicular structure inside them, and the fibrous component occurred mainly in the form of fine collagen fibers, which were sometimes collected into small bundles. The fibrosis was greatly overshadowed by the intense dust pigmentation, but it appeared to be the factor responsible for such lesions being just perceptible on palpation. The outlines of these retrogressive lesions were customarily stellate, while the surrounding and enclosed air spaces were emphysematous. It must be emphasized that this emphysema was focal in character, being restricted to those vesicles in the immediate vicinity of the dust foci. The walls of the emphysematous spaces (where these were not bounded by the dust foci) were thinned, their elastic fibers being either completely absent or showing attenuated and poor staining properties, while their reticulin fibers were also thinned and much less tortuous than usual. The focal emphysema occurring in combination with the focal dust lesions constituted the most striking feature of the disease. Respiratory bronchioles were seen in the substance as well as at the edges of some lesions, both formative and retrogressive. Generalized vesicular emphysema occasionally coexisted with the focal variety, but the latter was not obscured thereby."

Simple pneumoconiosis usually appears roentgenographically after 10 or more years of exposure to coal dust and may be associated with chronic bronchitis. Miners with simple pneumoconiosis often have normal pulmonary function values.

With continued exposure to coal dust, the roentgenographic picture reflects progression in the size and density of the nodules. After a period of 20 to 25 years of exposure to dust, complicated pneumoconiosis as well as extensive emphysema may develop.

Heppleston [5] described massive lesions of coal workers' pneumoconiosis (progressive massive fibrosis or complicated pneumoconiosis):

"Coarse, hyalinized collagen fibers were a prominent feature, arranged in bundles which sometimes ran in parallel formation and sometimes irregularly. The whorling characteristic of silicotic fibrosis did not occur in the massive lesions of these coal workers. Mingled with the fibrous tissue were black areas consisting of dust particles, lying either free or in small aggregates which probably represented the remains of dust-laden phagocytes. In many parts, however, the fibrous tissue was largely devoid of pigment. Included in massive lesions were small foci of chronic inflammatory cells, principally lymphocytes, together with many small vessels showing endarteritis or hyalinization. Larger vessels and bronchioles were inconspicuous. Ischemia due to vascular occlusion was in all probability responsible for the areas of colliquative necrosis which sometimes occurred in massive lesions. This necrosis was apparent only on cutting into the lesions, when a thick inky-black fluid, sometimes shimmering with cholesterol crystals, flowed out to leave a cavity with shaggy edges but no recognizable wall to demarcate it from the surrounding consolidation. The collagen fibers bordering the cavity were partially necrotic and terminated abruptly, so that the dust particles were no longer held in place but were cast off into the zone of liquefaction. Occasionally a cavity with a well-defined grayish wall occurred in a massive lesion. The lining of such cavities showed evidence of an inflammatory reaction suggestive of tuberculosis in the form of eosinophilic granular necrotic material with granulation tissue in which epitheloid cells or Langhans' giant cells might be present. It appears, therefore, that ischemic and infective cavities may be distinguished in coal workers' pneumoconiosis, as is also the case in silicosis. Small areas of caseation, evident to the naked eye in the substance of a few massive lesions, consisted of eosinophilic necrotic tissue. In some cases the latter was surrounded by tuberculosis granulation tissue, suggesting that this eosinophilic necrosis was tuberculosis even in the absence of specific histological features."

Pulmonary function studies generally show alterations when the disease has progressed beyond the roentgenographic classification of simple pneumoconiosis. These alterations, however, do not always correlate with abnormal roentgenographic findings. Dyspnea (shortness of breath) may occur once the progress has extended beyond the simple stage, particularly in the presence of respiratory infection and emphysema.

Complicated pneumoconiosis develops more rapidly in the central and upper portions of the lungs and results in extensive areas of necrotic lung tissue containing coal dust coalescing to form tumor-like masses in one or both lungs. With the development of this condition, there is such widespread destruction of lung tissue as well as blood vessels of the lungs that heart failure (cor pulmonale) frequently results.

3. Many investigators are of the opinion that the development of complicated pneumoconiosis may be related to factors other than the accumulative inhalation of coal mine dust since not all cases of simple coal pneumoconiosis develop into complicated pneumoconiosis.

Five theories have been advanced to explain the process of complicated pneumoconiosis. (a) One postulated that complicated pneumoconiosis was the result of tuberculosis infection. (b) Another held it was the result of simple coalescence of fibrotic nodules. (c) There also was the theory that infection with bacterial, mycotic, or viral agents played a role in its pathogenesis. (d) The concept of immunologic factors in the development of simple and complicated pneumoconiosis is currently receiving attention. The association of the rheumatoid factor with complicated pneumoconiosis in Caplan's syndrome has been responsible for much of this interest. (e) The total dust theory, presently supported by many investigators, suggests, roughly, that retention in the lung of a certain critical concentration of coal dust alters the type of tissue response in the development of complicated pneumoconiosis.

4. At the present time, there is no specific therapy for either simple or complicated pneumoconiosis. Recent trials with antituberculosis

drugs have not proven effective. The only successful preventive procedures at this time appear to be adequate environmental dust controls or removal of minimally affected miners from the dusty environment.

5. There is a time-dose relationship that seems to be related to the occurrence of simple coal pneumoconiosis in susceptible individuals. Evidence suggests that measuring the dust on the basis of respirable mass rather than the particle count is more important in both environmental control procedures and epidemiologic studies. Respirable mass concentrations refer to the total weight of particles less than 5 microns in size per unit volume of air. This concept is now supported by most investigators.

PATHOLOGY IN AMERICAN MINERS

Before this study was initiated in 1963, few studies had been conducted on the pathology of pneumoconiosis in American coal miners. The following cases (1, 2, and 3) are illustrative examples of case histories furnished by Doctors Werner Laqueur and Donald L. Rasmussen.* The sections of lungs are full, unstained lung slices mounted on paper according to the technique described by Gough.[4] The roentgenologic classification was made according to the new International Radiological Classification of the Pneumoconioses (Geneva—1958) as modified by the Public Health Service Panel of Radiologists.[6] (See Figure 16, page 48.)

Pathologic and roentgenologic data from these case studies, coupled with other information presented in this publication, leave little doubt that the pneumoconiosis as found in American workers does not differ significantly from that described by European and British investigators.

CASE 1

Age of death: 44 years.

Occupational history: 28 years in coal industry, all above ground. 16 years as machinist helper and electrician.

Smoking history: Not recorded.

Roentgenographic interpretation: Suspect pneumoconiosis (Category Z); abnormality of cardiac outline; Kerley's lines.

Clinical history: No respiratory disease. Angina pectoris for some years.

Main event leading to death: Coronary heart disease with multiple myocardial infarctions of different ages.

Pathologic material:

Gross: The parenchyma of both lungs was pale grayish with numerous small coal maculae, without obvious focal emphysema. Hilar nodes were enlarged and firm and heavily anthracotic.

Gough Section: No additional findings.

Microscopic: (not shown) Minute aggregates of dust-laden phagocytes were seen in center of secondary lobules. No focal emphysema was present. The lymph nodes showed concentric hyaline nodules with minimal dust.

Conclusion: Although classical signs of coal workers' pneumoconiosis were almost nonexistent in the lung, evidence of occupational exposure was found in the lymph nodes, which reflected tissue reaction to free silica.

CASE 2

Age at death: 56 years.

Occupational history: 34 years as miner; 12 years as coal loader; 22 years tipple maintenance. Retired 5 years before death.

Smoking history: One-half package of cigarettes per day, unknown number of years.

Roentgenographic interpretation: Simple pneumoconiosis (Category 3p) with abnormality of the pleura and significant displacement or distortion of the intrathoracic organs.

Clinical history: No respiratory distress. Mild emphysema. Heart attack 5 years before death.

Main event leading to death: Cerebral hemorrhage.

Pathologic material:

Gross: Both lungs were grossly very similar. Emphysema was more pronounced in the left lung with a few subpleural blebs up to 1 centimeter in diameter. Many coal maculae were seen, more in the upper than in the lower lobes. There was mild focal emphysema.

Gough: Throughout both lung fields there were many macules, consisting of a black center surrounded by 1 or 2 millimeter

*Applalachain Regional Hospital, Beckley, W. Va.

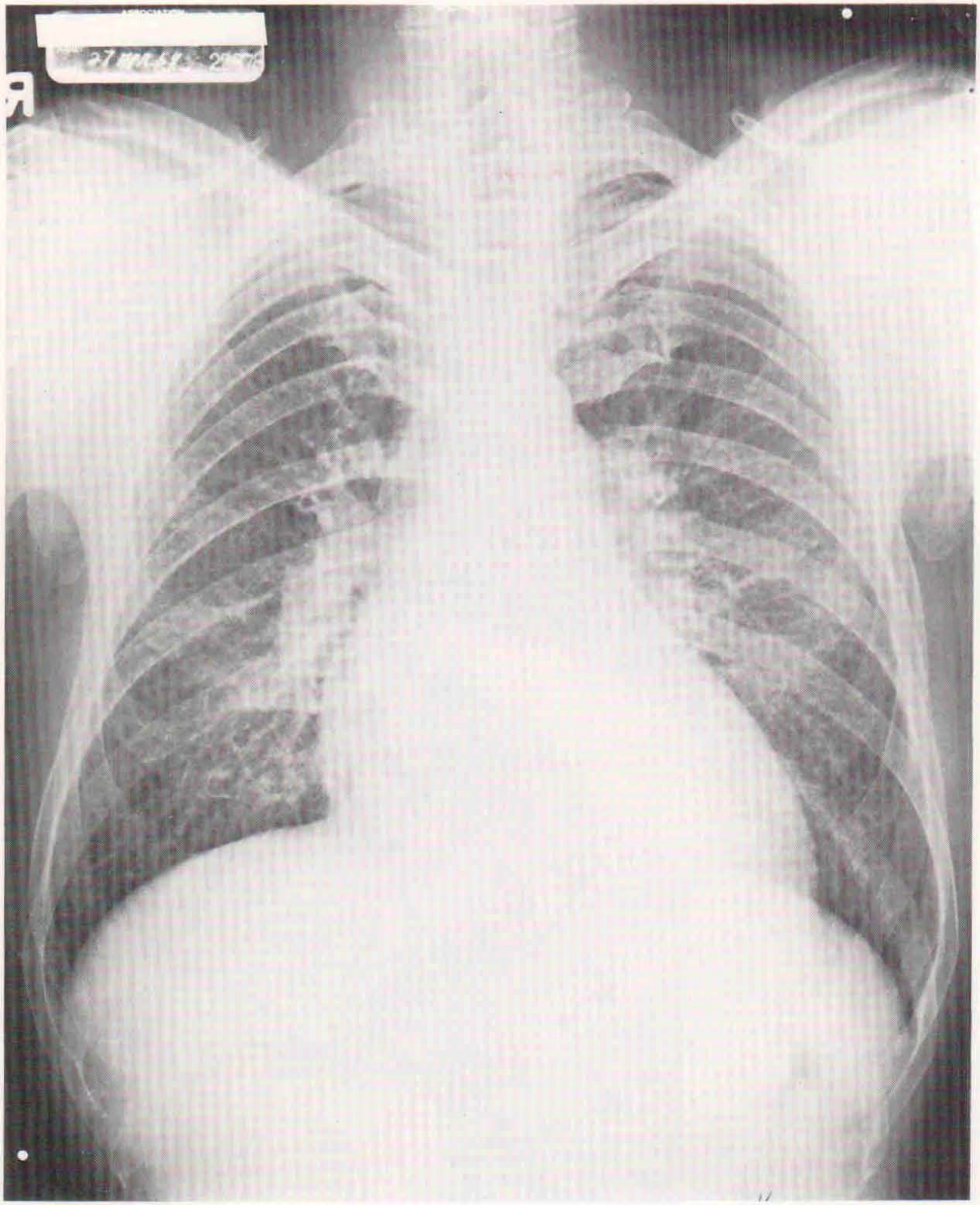

Figure 1.—Case 1. Roentgenogram, Category Z, suspect pneumoconiosis

Figure 2.—Case 1. Gough section of lung

air spaces. More emphysema was seen in subpleural areas. There was minimal dust deposition outside of the maculae. There was passive congestion of central areas of the lung.

Microscopic: (not shown) There were minimal-layered dust maculae with distribution around respiratory bronchioles, with almost no fibrosis. Vascular mantles in and around adventitia were seen. The vessels, by and large, showed no sclerosis.

Conclusion: Coal workers' pneumoconiosis, simple, macular.

CASE 3

Age at death: 62 years.

Occupational history: Coal miner for 41 years with rare intervals outside mines; last mining experience 8 years before death.

Smoking history: One package of cigarettes per day for 30 years.

Roentgenographic interpretation: Complicated pneumoconiosis (Category C) with a simple pneumoconiosis background (Category 2r) and emphysema.

Clinical history: Patient had had several admissions to hospital for upper respiratory infections and bronchitis. He reported a chronic cough 13 years before death and had had hemoptysis on several occasions. On last admission, patient had severe dyspnea with 50 percent collapse of the right lung and severe bronchospasm.

Main event leading to death: Chronic cardiopulmonary disease with congestive heart failure and terminal pneumonia. Contributory—spontaneous pneumothorax.

Pathologic material:

Gross: Contour of lungs was very irregular due to contracted areas in both apices formed by large hard masses. The pleurae generally were not thickened. Emphysematous bullae formation was not remarkable, although there were some small blebs up to 1 centimeter in diameter. There was increased firmness in the bases of both lower lungs. Hilar lymph nodes were large and rather firm and solid black. Right lung—the pleura was greatly thickened and opaque over the left posterior lateral and apical portions. Most of the middle lobe and adjacent areas of upper lobes consisted of consolidated black fibrotic masses that were very firm and contained only a few recognizable bronchi. The black pigment rubbed off on the above examination. The mass seemed to fill the whole width of the lung from the hilum to the lateral wall. Otherwise, the emphysema was mostly marginal. The bases of the lower lobe contained numerous emphysematous blebs, many of which were interconnecting. There were also small nodules noted.

Gough Section: This is a classical example of massive fibrosis developed upon a background of simple nodular pneumoconiosis. Slight focal emphysema was noticed. A few marginal emphysematous blebs mentioned before were seen in this section.

Microscopic: (not shown) Large fibrotic areas were composed of broad bands of hyalinized collagen with abundant pigment. Small necotic areas were seen. Bronchi and vessels were absent. There was some fibrosis of alveolar walls in adjacent lung tissue and various degrees of acute inflammatory infiltration. Foci of organizing pneumonia were also present. Lack of marked emphysematous changes was striking.

Conclusion: Coal workers' pneumoconiosis, complicated with ischemic necrosis of fibrotic areas.

European Experience

Although the medical literature of the 19th century contained frequent warnings that coal miners suffered from an unusual chest disease,[7] the first investigation was not made until 1928. In that year, Collis and Gilchrist[8] published a paper that precipitated a long and detailed investigation of chest diseases among bituminous coal workers in the United Kingdom.

Studies were initiated in 1936 by the Committee on Industrial Pulmonary Diseases of the Medical Research Council in Great Britain, and during the intervening years, great effort has been invested by the Council and the National Coal Board in studies of the etiology, pathology, and prevention of diseases due to coal dusts.[9, 10]

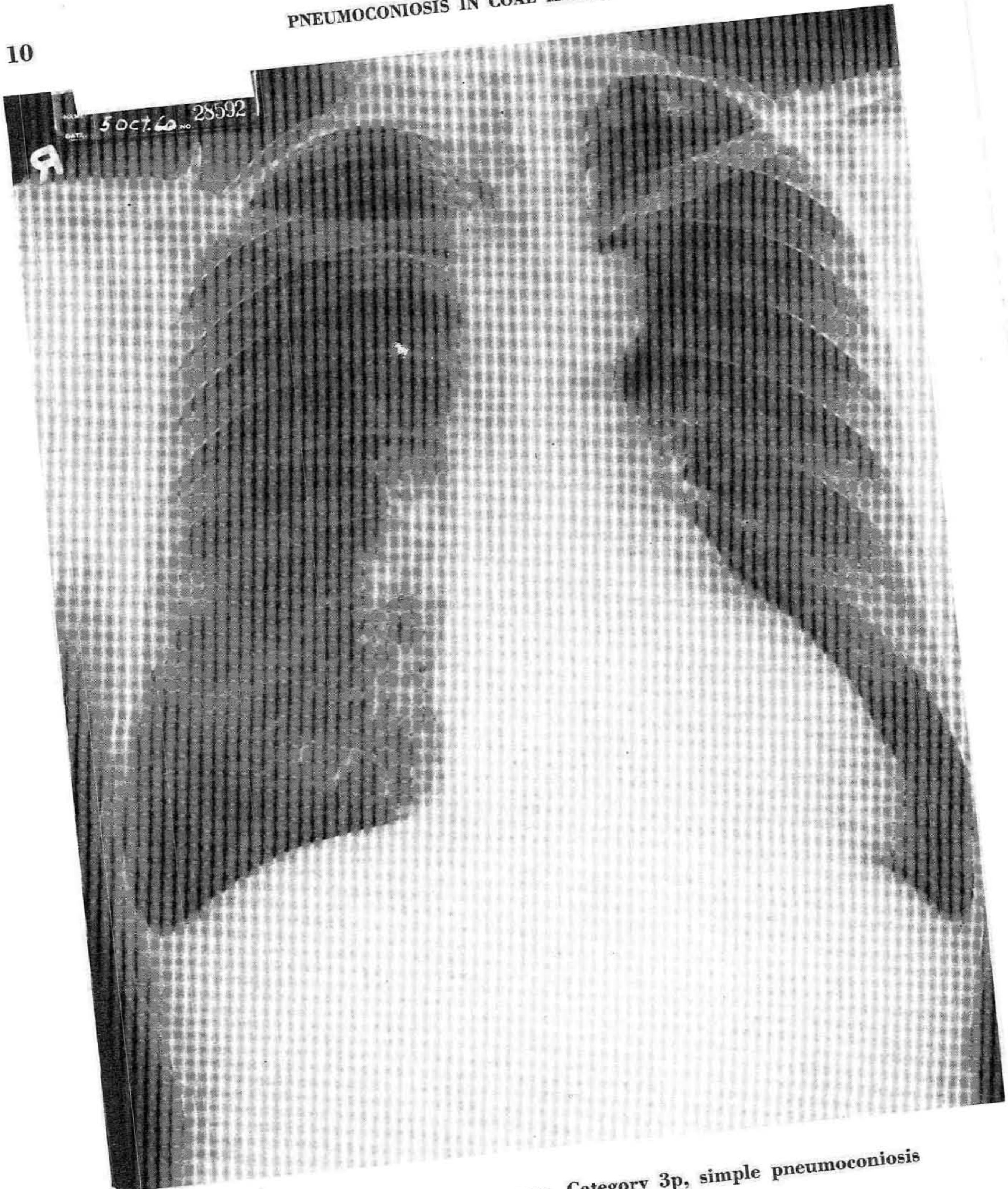

Figure 3.—Case 2. Roentgenogram, Category 3p, simple pneumoconiosis

Figure 4.—Case 2. Gough section of lung

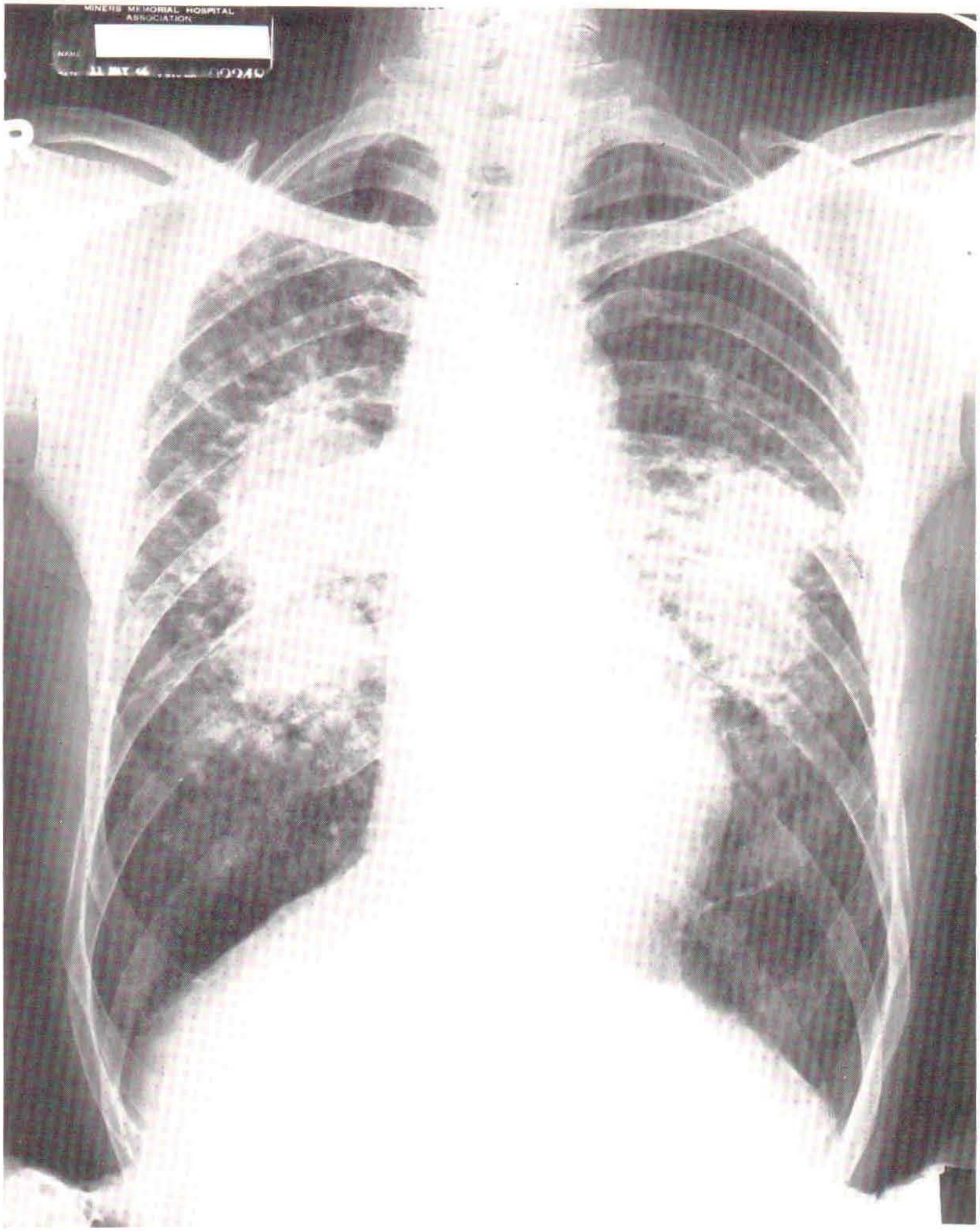

Figure 5.—Case 3. Roentgenogram, Category 2rC, complicated pneumoconiosis

Figure 6.—Case 3. Roentgenogram, closeup, right hilar area

Figure 7.—Case 3. Gough section of lung

Although coal pneumoconiosis was recognized on the European continent about 1935, the establishment of the European Coal and Steel Community in 1952 brought about a coordinated effort to study and prevent the disease. One of the aims of the Community is to provide for better worker health in the coal and steel industry. By 1962, large sums of money for research on industrial health and the prevention of accidents, with major emphasis on silicosis and other pneumoconioses, had been allocated. Coal pneumoconiosis was recognized as a compensable disease in each of the European coal producing countries. In some countries, the compensation cost for coal pneumoconiosis was greater than for all other occupational diseases combined. Through funds from the European Coal and Steel Community, many excellent research laboratories have been developed, and their investigations have added much to the fundamental knowledge of the pathology and physiology of all dust-induced diseases, with special emphasis on coal pneumoconiosis.

Preventive measures employed in the European mines differ in detail from country to country, but all have the common factors of environmental control and medical surveillance of the individual. Environmental control is based primarily upon dust suppression: water infusion of the coal face, water sprays during blasting, and sprays on all automatic hauling equipment. Ventilation is used extensively as a control method, and additionally, many mines require the use of respirators.

Instruments used for measuring dust concentrations also vary from country to country, but most investigators endorse the concept of a mass standard. In Germany, the Tyndallometer is still the instrument of choice,[11] whereas in the United Kingdom, the thermal precipitator is the standard instrument.[12] The Netherlands and Belgium are presently using a mass standard [13] based on total dust exposure rather than respirable dust.

In most European countries, the primary responsibility for environmental control is vested in the mining companies, and many have effective dust and medical control programs. The dust concentration is usually categorized into three areas: Safe, marginal, and unsafe. In practically all cases, the standard is a function of the stone (inorganic material) content and the concentration of the respirable dust less than 5 microns in size. In Belgium, France, Germany, the Netherlands, and the United Kingdom, there are extensive research programs in dust evaluation and control, usually under the sponsorship of a government agency.

Walton [14] summarized coal mine dust standards in use in 1965 by the major coal producing countries and the National Coal Board. In most West European countries, emphasis is placed on the medical control of the miner, which includes preemployment and frequent periodic examination. Once an individual develops early pneumoconiosis, medical practice requires that he be placed in an area of "safe dust" concentration. If the disease continues to progress, he is removed entirely from dust exposure. In all of the member countries of the European Coal and Steel Community, the principle of partial disability due to coal pneumoconiosis is well accepted.

American Studies of Coal Miners Before 1957

In the United States, there is no body of information on coal workers' pneumoconiosis comparable to that existing in Europe and the United Kingdom. For this reason, American investigators have largely depended on the views and findings of European scientists. Before about 1952, many investigators assumed that bituminous coal did not produce a disabling pneumoconiosis although pneumoconiosis among anthracite miners had been studied by American investigators. Recognizing the interest in the health of bituminous coal miners, the Division of Occupational Health* in 1954 compiled an annotated bibliography on the subject that summarized the major studies of American and British investigators.[15]

The first major epidemiologic study of chest diseases in the United States was conducted among the anthracite miners of eastern Pennsylvania by the Division of Industrial Hygiene between 1928 and 1931.[16] The exhaustive study of the nature and development of anthracosilicosis was based on the examination of 2,711 men in Pennsylvania anthracite mines. The study also considered the findings for 135 disabled ex-miners, as well as a

* In this publication, the terminology Division of Occupational Health, Division of Industrial Hygiene, Occupational Health Program, and the Bureau of Occupational Safety and Health all refer to the same administrative unit.

smaller group examined in a state tuberculosis sanatorium. Pneumoconiosis that results from breathing air containing the dust generated in the various processes involved in the mining and preparation of anthracite coal is designated as anthracosilicosis; this is a modified form of silicosis** caused by inhalation of silica dust intermixed with considerable amounts of carbon dust. Diagnosis was based on three important classes of findings: History, clinical examination, and roentgenographic examination.

Of the various contributory factors observed in the development, course, and final effect of the disease, pulmonary infection and cardiac impairment appeared to be the most important. This was found to be especially true in the advanced stages of the disease. Among the entire group of employees examined, about 23 percent had evidence of anthracosilicosis. The correlation between exposure to dust and the pathologic findings left little doubt as to the etiologic significance of coal mine dust.

Mortality rates from respiratory diseases were found to be much higher among anthracite workers than in the general, adult, male population. The data indicated that underground workers, working in the absence of dust, did not develop anthracosilicosis.

Little evidence was available by 1942 to indicate that bituminous coal miners developed chest diseases with the same frequency or with the extensive pathologic changes observed in the anthracite miners. In 1941, Clarke and Moffett [17] reported the results of chest roentgenograms and occupational histories of 774 southern Appalachian bituminous coal miners taken in a study designed to determine the extent to which silicosis was present in soft coal miners. A tendency of bituminous coal miners to develop presilicotic and silicotic lung changes after prolonged employment was evident. At the mine where the study was conducted, 2 percent of the workers' chest roentgenograms showed presilicotic and 1 percent showed silicotic nodulation. These changes occurred principally among underground cutting machine operators and coal loaders. The shortest exposure period necessary to produce nodulation was observed in a rock driller who had worked at his trade for 11 years. The so-called presilicotic and silicotic nodulations were not defined in this paper.

Division of Industrial Hygiene investigators substantiated these findings in a study of bituminous coal miners in Utah.[18] Medical and roentgenographic examinations found anthracosilicosis to be the principal occupational disease of workers whose only experience in dusty trades had been in the bituminous coal mines in Utah. Among the 507 workers studied, 16 cases (3.2 percent) of anthracosilicosis were diagnosed, only one of which evidenced moderate or great disability. Of these 16 cases, 13 occurred in persons who had spent a large proportion of their working time at the face. The incidence of anthracosilicosis increased regularly with the severity and duration of exposure. No cases were found among workers with less than 10 years of employment in bituminous coal mines, and only two cases were found among workers with an average weighted dust exposure of less than 20 million particles per cubic foot of air. Reinfection or adult-type tuberculosis was found in 13 of 507 workers. One apparently healed case of tuberculosis was found in the 16 workers with anthracosilicosis.

Five material samples obtained in the vicinity of face workers ranged in total silica content from 3.2 to 68.4 percent, whereas the quartz content of these samples varied from less than 1 to 11 percent. Hence, face workers, who comprise 55 percent of underground employees, were exposed to relatively small amounts of quartz.

In 1942, Jones [19] attempted to demonstrate that silicosis in soft coal miners was not a rare disease and that "miners' asthma" and anthracosilicosis were one and the same disease. This was accomplished through a study of 86 West Virginia bituminous coal miners with evidence of silicosis. He demonstrated that the greater number of cases and disability occurred in the decades from 40 to 60 years of age. All of those in the disabled group had spent a large part of their mining life as trimmers, motor runners, coal shooters, or machine men. These occupations appear to be the most hazardous because of the silica-dust exposure.

** Silicosis, sometimes used synonymously with anthracosilicosis, is a chronic condition of the lungs caused by the inhalation of air containing finely divided particles of silica. Although the term implies that silica is the fundamental cause, Gough found that similar pathologic and clinical features occur in laborers who work in an atmosphere of coal dust in which the percentage of silica is low.

He concluded that disability is not necessarily in proportion to the total number of years employed in the mining industry, but depends more on the occupation. A lesser but definite degree of anthracosilicosis occurred in loaders and other underground workers. Post mortem studies showed that pneumoconiosis in soft coal miners may be of two types. In the first, the well-known deeply pigmented lung may show definite changes of associated silicosis as a result of many years of exposure to bituminous coal dust that contains silica. In the second, there may be advanced conglomerate pulmonary silicosis with a minimum of anthracotic pigmentation.

By 1949, it was becoming apparent that pneumoconiosis was a major health problem among bituminous as well as anthracite coal miners. Gordon *et al.*[20] reported in considerable detail the pathologic, clinical, and physiologic aspects of anthracosilicosis, defining "anthracosilicosis" as "the condition of progressive pulmonary fibrosis with conglomeration of nodules in the advanced stages, caused by the inhalation of carbon and silica, and characterized clinically by dyspnea, with varying degrees of disability." The broader designation "coal miners' pneumoconiosis," used less frequently at that time, referred to the bizarre and varied lesions of pulmonary fibrosis, with emphysema, marked areas of conglomeration, and distention of the bronchi and other thoracic structures. In their report on a study of coal miners admitted to a hospital in West Virginia, Gordon and his associates indicated that dyspnea in varying degrees may be expected in 85 to 90 percent of coal miners with moderately advanced or far advanced anthracosilicosis. A feature of the onset was observed to be the insidious and gradual impairment of breathing, accentuated by bouts of intercurrent respiratory tract infection. The actual onset may have preceded by several years the time when the miner decided to stop work because of difficult breathing. One curious aspect they observed was that dyspnea became more apparent during or following a respite from work, as in the prolonged shutdown of coal mines.

The physical signs did not always disclose the extent of the underlying disease. This was emphasized repeatedly when the findings of the physical examinations were compared with the roentgenograms and the pathology. A remarkable feature of the comparison was that the extensive changes may have been almost entirely masked until intercurrent infection or a failing pulmonary circulation accentuated the underlying disease. Coal miners were found to be especially susceptible to tracheobronchitis and localized pulmonary congestion.

Gordon *et al.* employed physiologic methods to study the nature of breathing impairment in anthracosilicosis. Their study of over 150 anthracite coal miners and 25 bituminous coal miners with respiratory complaints attributable to prolonged exposure (20 to 40 years) to dust inside coal mines indicated that alterations in maximum breathing capacity, with few exceptions, were more reliable criteria of pulmonary impairment than the deviations in vital capacity. Studies of the respiratory gas exchange, including analysis of the expired air and arterial blood drawn directly from the brachial artery, provided important information pertaining to the distribution of the inspired air and the pulmonary blood flow.

In 1952, information available to the Division of Occupational Health indicated that a major cause of morbidity among bituminous coal miners was chronic diseases of the respiratory system. A study of case material in various medical clinics in the Appalachian area demonstrated the presence of a disease in bituminous coal miners similar in its roentgenographic appearance to that described by Gough and others in the United Kingdom.[21] From this information, coal pneumoconiosis was assumed to be prevalent among American coal miners and its appearance at this time was related to the introduction of mechanical mining equipment.

American Studies of Coal Miners From 1957

Subsequent studies by other investigators have developed more quantitative evidence that there is a severe chest disease problem among the miners in the American bituminous coal industry. In 1957, Levine and Hunter [22] reported finding pneumoconiosis in a group of 153 miners from the Ohio River coal fields that was roentgenographically identical to that described by the British workers. In an attempt to assess the extent of the pneumoconiosis problem in the bituminous and anthracite coal mining industry in Pennsylvania, Lieben, with others, undertook a series of investigations and studies. A review of death certificates in the Commonwealth of Pennsylvania for 1959 and 1960 revealed that 2,138 (77 percent) of the 2,772 death certificates listing pneumoconiosis, silicosis, and anthracosilicosis as the primary or contributory cause of death occurred in six counties of the anthracite region of Pennsylvania.[23] Only 289 (1 percent) of these deaths occurred in the western Pennsylvania bituminous region. Records of the National Office of Vital Statistics of the Department of Health, Education, and Welfare further revealed that 50 percent of the pneumoconiosis and approximately 93 percent of the anthracosilicosis deaths in the United States were reported from Pennsylvania.

Since evaluation of death certificates and analysis of occupational disease compensation statistics does not contribute information about the problem among working miners, a roentgenologic study of almost 16,000 miners was conducted from 1959 to 1961 among central and western Pennsylvania bituminous coal miners.[24, 25, 26] In central Pennsylvania, 29 percent of the 4,200 working bituminous miners examined had roentgenographic evidence of pneumoconiosis, whereas 11 percent of the 8,200 western Pennsylvania working bituminous miners studied showed such evidence.

In both study groups, the prevalence of pneumoconiosis increased with age and length of exposure. In central Pennsylvania only 16 percent of the working miners under age 45 (299) had roentgenographic evidence of pneumoconiosis whereas 41 percent of those in the age group 45 to 64 (926) had pneumoconiosis. Of the retired miners, 55 percent (437) had roentgenographic evidence of pneumoconiosis. In western Pennsylvania, 4 percent of 3,425 working miners under 45 years of age, 15 percent of 4,633 working miners over 45 years of age, and 29 percent of 1,939 retired miners had the disease.

In both studies, subjective symptomatology and roentgenographic findings did not necessarily agree. Of the 3,368 central Pennsylvania examinees without evidence of pneumoconiosis, 45 percent (1,510) complained of shortness of breath. In the group of 750 miners with coalescent lesions, 32 percent (244) denied having shortness of breath. There were fewer complaints of shortness of breath in western Pennsylvania. Of the 9,301 examinees with pneumoconiosis, only 21 percent (1,966) complained of shortness of breath. In the group of 622 examinees with coalescent lesions, 60 percent (377) denied being short of breath.

In this series of roentgenograms of bituminous miners, all types of roentgenologic changes typical of anthracite miners were observed. Opacities varying from micronodular densities to large massive lesions were found. Emphysema was not a prominent finding. An unexpected observation was the presence of micronodular densities, reticular shadow patterns, and coalescent and massive lesions in the lower lobes. In some instances, the densities were more dominant in the lower lung fields than in the upper, the opposite of that found in anthracite miners. Pleural changes were similar to those expected in anthracosilicosis.

The results of the study, although significant, are not conclusive with respect to prevalence rates. Because of certain circumstances, only miners volunteering for examination formed the basis of the study; for this reason, the population studied may not have been a representative sample. Nevertheless, the study demonstrated that Pennsylvania had a pneumoconiosis problem of greater magnitude in its bituminous mine population than was hitherto believed.

An environmental study of dust exposure in 14 bituminous coal mines was undertaken concurrently with the above medical study of miners in central Pennsylvania. According to the authors, Baier and Diakun,[26] the findings of the environmental study are incomplete and permit only tentative conclusions. They found dust concentrations and dust compositions at the time of the survey were not necessarily representative of the actual exposures of the various individuals during their lifetime. Of more than 300 dust samples collected in the working environment, 90 percent showed less than 2 percent free silica. This finding gave rise to the hypothesis that either low concentrations of free silica or high concentrations of coal dust or a combination of the two play a significant role in the production of pneumoconiosis.

In 1963, Baier and Diakun[27] reported on a study of dust conditions in 24 anthracite coal mines in eastern Pennsylvania. This study was undertaken primarily to locate sources of airborne dust created by the mining operations. Dust exposure levels ranged from 100,000 to approximately

5½ billion particles per cubic foot and varied with the location of the mine. Free silica content of materials found at various locations and operations varied considerably from sample to sample and even during the same operation. From the 83 samples collected, it appeared that free silica exposure was greater in the anthracite mines than in bituminous coal mines. The median particle size of dust ranged from 0.308 to 1.560 microns, with an average size of 0.611 microns. The nature of certain operations precluded an accurate estimate of miners' exposures.

COAL MINE DUST STANDARD

Until very recently there has been no generally accepted hygienic standard for exposure to coal mine dust in the United States.* Threshold Limit Values of the American Conference of Governmental Industrial Hygienists for nuisance particulates [28] have been generally used as a guide. Since bituminous coal contains only a small amount of free silica, the value in general use, at least since 1950, was 50 million particles per cubic foot of air. However, the U.S. Bureau of Mines recommends a limit of 25 million particles per cubic foot of air. Following the introduction of standards based on the concept of gravimetric sampling by the American Conference of Governmental Industrial Hygienists in 1965, the value of 15 milligrams per cubic meter of air was applicable.

ECONOMIC SIGNIFICANCE OF COAL PNEUMOCONIOSIS

Although the scope of this study did not include a detailed analysis of economic aspects, a few comments on the economic significance of coal pneumoconiosis would seem appropriate.

Estimates of the number of coal miners with pneumoconiosis range from 38,000 to 125,000. The former is a projection of the prevalence percentages reported in this study to the total population of active coal miners (140,000) and to the estimated number of inactive or retired coal miners (70,000 on United Mine Workers retired rolls plus 50,000 not on the rolls). The latter estimate of 125,000 was made by Dr. Lorin E. Kerr, United Mine Workers of America Welfare and Retirement Fund.[29] Dr. Kerr also estimated that about 50,000 of these miners are probably disabled by the disease.[30]

In March 1969, about 28,000 coal miners in Pennsylvania were receiving compensation for disability from coal workers' pneumoconiosis in the amount of $141 million per year, and about 6,000 cases were pending.[31] Of the 28,000, 9,029 were disabled bituminous coal miners. Although it is impossible to estimate the actual or potential compensation costs for the entire Nation, the figures from Pennsylvania indicate the high cost of the disease.

Compensation costs do not reflect the total economic problem. There are other costs that have not yet been determined. These include the cost of medical and hospital expense, loss of earning power, welfare, physical and vocational rehabilitation, and economic deprivation of the families of the affected workers.

* On December 9, 1968, the Department of Health, Education, and Welfare recommended to the Department of the Interior an interim standard for respirable dust levels in bituminous coal mines. This recommendation specified an interim standard for respirable dust in coal mines not to exceed 3 milligrams per cubic meter as measured by the Mining Research Establishment (MRE) horizontal elutriator instrument, or 1.6 milligrams per cubic meter as measured by the Atomic Energy Commission (AEC) cyclone instrument. This recommendation was based on data and sources of information particularly from Great Britain and the Commonwealth of Pennsylvania, which are not contained in this report.

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SECTION II

Plan of Study of Coal Miners' Pneumoconiosis in Appalachian Bituminous Coal Miners

Plan of Study of Coal Miners' Pneumoconiosis in Appalachian Bituminous Coal Miners

MILDRED A. KENDRICK, Ph.D., and PHILIP E. ENTERLINE, Ph.D.

In August 1962, the Division of Occupational Health began plans for a study of chronic chest diseases among bituminous coal miners. Planning sessions were held with coal operators' associations, with officials of the United Mine Workers of America and the Bureau of Mines, and with officers of the health departments and medical associations of the concerned States. The objectives for this study were to determine the prevalence of chest disease in bituminous coal miners, to define its relationship to their working and living environment, and to identify preventive medical and engineering measures. The first objective was the prime undertaking in the study; the second was studied in part; the third has not yet been accomplished.

In previous studies of the prevalence of pulmonary disease among American bituminous coal miners, the results have been marred by shortcomings in the structure of the studies. First, the response was poor in terms of both percentages and selection. Participation was voluntary, and those who participated, because they were self-selected, may not have been a true sample of the total coal mining population. There was, for example, no way of knowing whether the responding group was more or less healthy than the nonresponding group. Thus, there was no way of relating the results from the responding group to the entire population of interest.

A second shortcoming seen in some of the previous studies was the restriction of examination to men currently working. Such a sample is probably highly selective in terms of health. Certainly, the man so incapacitated as to not be able to work will not be included, and quite probably poor health might be one of the major reasons for leaving the mining industry. A worker with poor health and a high absentee rate may be among the first laid off in a period of reduced employment and may not be hired back at all. It might be contended that a disease created by a work environment would be most heavily concentrated among persons who have, through age or illness, completed their active work life and are not represented in the labor force.

A third weakness lies in the difficulties in disentangling the etiologic effects of the work environment from general living conditions. This problem is particularly great in dealing with respiratory conditions with multiple etiologies.

The Division of Occupational Health was charged with developing a study that would improve upon the results of the earlier studies. Two epidemiological approaches were planned. The sample of men selected for examination would be drawn randomly from lists of employees in mines regularly employing 15 or more persons underground and from lists of men who had once been miners but were no longer thus employed. Secondly, examinations were made on samples of mining and nonmining populations drawn from bituminous coal mining areas. Examination of the latter group, discussed in Section IV of this report, provided information about respiratory symptoms in the general population living in the area where coal mining occurs. In addition, this provided data on one of the weaknesses of earlier studies (that the radiologists may be influenced in specific examinations dealing with miners) by seeing how much pneumoconiosis would be detected when coal miners' roentgenograms were mixed with those of other workers.

For the study of present and former bituminous coal miners, the geographical area selected extended over portions of seven eastern States known as the Appalachian region of the Nation. This area (Figure 8) is where the vast majority of coal miners in the United States live and work.

Funds and personnel available for the study

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permitted sample sizes of 2,000 employed miners and 1,000 nonworking miners. The sampling scheme for employed miners involved a two-stage random selection of mines with stratification and control of subsample size, using selection probabilities proportional to size, and with random selection of men for certain mine sizes. The general scheme is described by Cochran.[1] This selection

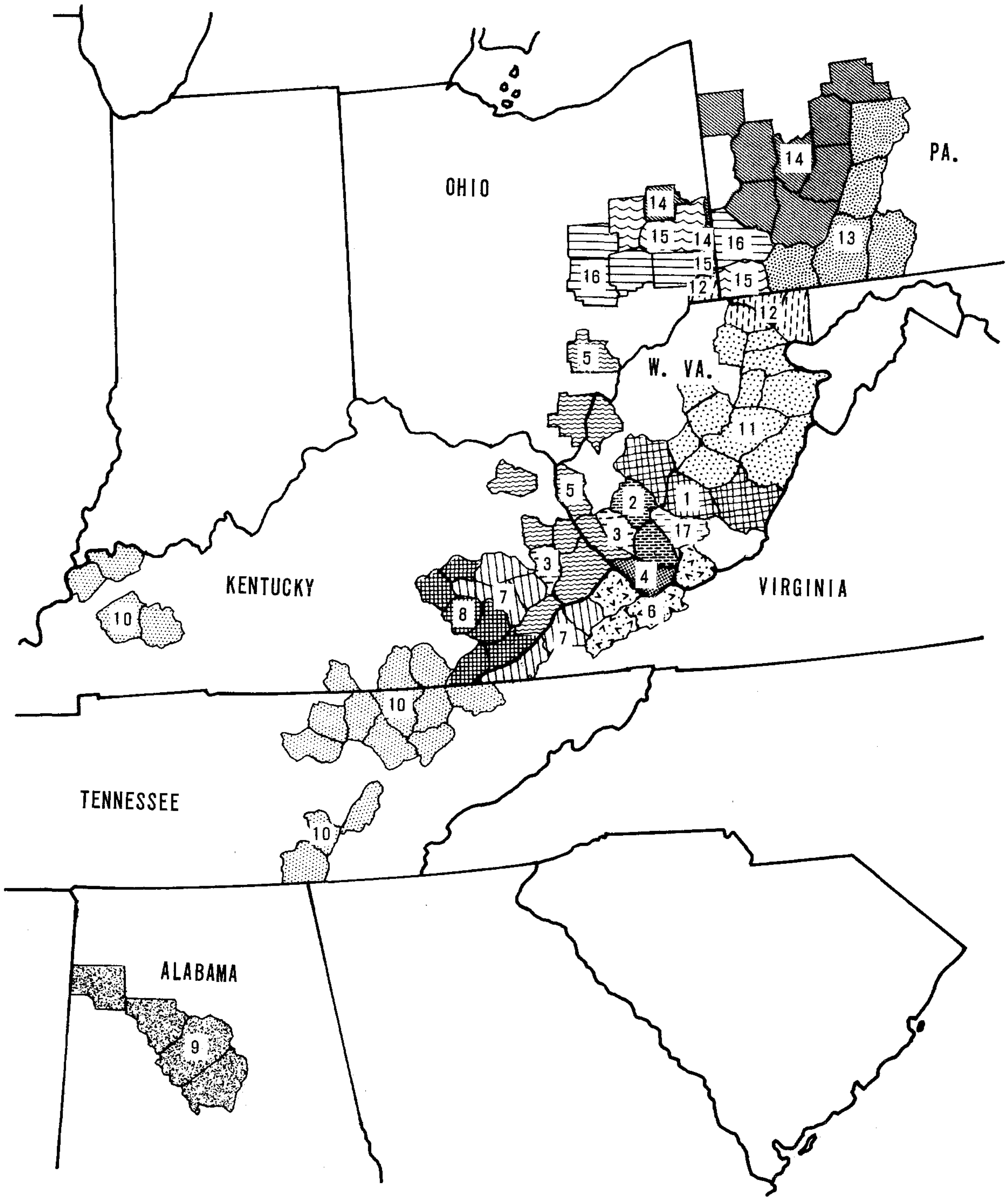

Figure 8.—Map of counties comprising Appalachian region bituminous coal mine study (numerals refer to strata given in Table 1)

technique provided the Division of Occupational Health with a measurable degree of assurance that the estimates made concerning respiratory diseases and conditions apply to all miners in the region. Each working miner chosen for the study represented 40 other miners; each mine chosen represented 25 mines. The success of this phase of the study depended heavily upon the cooperation of the mine operators and of the miners chosen to participate.

The most recent census (1960) showed about 100,000 employed miners within the Appalachian region. The number of former miners was believed to be greater than 100,000, but no exact count was available. There were 97 counties in the Appalachian region where there was at least one mine with 15 or more workers. The sample of working miners was drawn in stages from the total population of working miners in these 97 counties according to the following plan:

(1) The 97 counties were grouped geographically into 17 strata averaging about 6,000 miners each (Table 1).

(2) From each stratum, one or more counties

TABLE 1—*Counties comprising each stratum.*

Stratum	Counties
1	KANAWHA, W. VA.[a]
	Fayette, W. Va.
	Greenbrier, W. Va.
2	Boone, W. Va.
	WYOMING, W. VA.[a]
3	LOGAN, W. VA.[a]
	Floyd, Ky.
4	McDOWELL, W. VA.[a]
5	Athens, Ohio
	Gallia, Ohio
	Martin, Ky.
	Pike, Ky.
	Mason, W. Va.
	Mingo, W. Va.
	Wayne, W. Va.
	Carter, Ky.
	Johnson, Ky.
	LETCHER, KY.[a]
6	BUCHANAN, VA.[a]
	Russell, Va.
	Tazewell, Va.
	Mercer, W. Va.
7	Dickenson, Va.
	LEE, VA.[a]
	WISE, VA.[a]
	Breathitt, Ky.
	Knott, Ky.
	Perry, Ky.
8	Bell, Ky.
	Clay, Ky.
	HARLAN, KY.[a]
	Jackson, Ky.
	Leslie, Ky.
	Lee, Ky.
9	JEFFERSON, ALA.[a]
	Marion, Ala.
	SHELBY, ALA.[a]
	Walker, Ala.
10	Anderson, Tenn.
	Campbell, Tenn.
	Claiborne, Tenn.
	Fentress, Tenn.
	Marion, Tenn.
	Morgan, Tenn.
	Overton, Tenn.
	Putnam, Tenn.
	Rhea, Tenn.
	Scott, Tenn.
	Sequatchie, Tenn.
	Clinton, Ky.
	McCreary, Ky.
	Whitley, Ky.
	Henderson, Ky.
	HOPKINS, KY.[a]
	Muhlenberg, Ky.
	Union, Ky.
11	Clay, W. Va.
	BARBOUR, W. VA.[a]
	Braxton, W. Va.
	Gilmer, W. Va.
	Harrison, W. Va.
	Nicholas, W. Va.
	Pocahontas, W. Va.
	Randolph, W. Va.[b]
	Taylor, W. Va.
	UPSHUR, W. VA.[a]
	Webster, W. Va.[b]
12	Marshall, W. Va.
	Marion, W. Va.
	Monogalia, W. Va.
	PRESTON, W. VA.[a]
13	Bedford, Pa.[b]
	Cambria, Pa.
	Clearfield, Pa.
	Somerset, Pa.
	FAYETTE, PA.[a]
14	Armstrong, Pa.
	Elk, Pa.
	Indiana, Pa.
	Jefferson, Pa.
	Westmoreland, Pa.
	ALLEGHENY, PA.[a]
	Butler, Pa.
	Mercer, Pa.
	Carroll, Ohio
	BROOKE, W. VA.[a]
15	GREENE, PA.[a]
	Harrison, Ohio
	Jefferson, Ohio
	Tuscarawas, Ohio
	Ohio, W. Va.
16	WASHINGTON, PA.[a]
	Belmont, Ohio
	Coshocton, Ohio
	Guernsey, Ohio
	Muskingum, Ohio
17	RALEIGH, W. VA.[a]

[a] Sample county.
[b] County added to sample to supply a sufficiently large number of nonworking miners.

were selected at random, with the probability of selection proportional to the number of working miners in the county or counties. Stratification ensured representation from all parts of the Appalachian region. Counties with less than 165 working miners were coupled with an adjacent county before sample selection.

(3) Insofar as possible, in each sample county, one large and two small mines were randomly selected from all possible samples of one large and two small mines, based on the mine population at the time of selections. The large and small mines were separated at the 50-employee level. This amounted to stratification by mine size and allowed for possible differences in the prevalence of disease between these two sizes of mines.

(4) From the sample mines chosen for each county, about 165 working miners were selected for examination. This number allowed for about one-third nonresponse rate.

(5) In mines employing more than 50 workers, a simple random sample of 50 miners was selected for examination. In mines employing less than 50 workers, all miners were selected. This provided for efficient use of staff and equipment by making each "stand" about equal in length (about 1 week).

(6) The selection of miners for a particular mine was made from the payroll roster. Care was observed so that the latest possible roster was used in the selection.

Because all workers in small mines were examined whereas only a sample was examined from large mines and because one county (Raleigh, W. Va.) was selected with certainty, the sample was not self-weighting. The introduction of appropriate weights did not change the findings appreciably, however, and in the interest of simplifying this report, data in Sections III and IV are actual rather than weighted counts.

The sampling scheme did not make any provisions for the substitution of either a man or a mine if, for any reason, the man or mine initially selected could not be included. A selected man's failure to qualify for examination might be due to sickness, layoff, strike, shutdown, refusal of the mine operator to participate or to allow the miner to participate, or change in the number of men employed in the mine to less than 15. The owners of three mines refused participation, one mine was on strike, three mines were shut down, and four mines no longer had a sufficiently large underground staff to be included. The reaction of the working miners in participating mines was very cooperative.

Defining and selecting a population sample of nonworking or former miners presented a serious problem since no roster was available, and the selection plan finally adopted was a compromise with the original objectives. Under the plan, nonworking miners were defined as those men between 35 and 65 years of age who had been miners for a portion of their working lives and were currently paying nonworking dues to the United Mine Workers of America. The lower age cutoff was applied to ensure that the participants could have had a significant work history in the mine; the upper age cutoff was decided upon because a comparison with working miners was desired and almost none of these was over the age of 64. Thus, the nonworking miner study population does not fully represent the complete population of former coal miners in the Appalachian region. It is believed, however, that this is a useful and informative sampling of men with a significant work history in the coal mining industry who remained in the Appalachian region. Groups known to be omittted were (a) former miners who had discontinued membership with the United Mine Workers of America in the Appalachian region, and (b) men paying working dues but who were not actually working in a mine and thus were not eligible for selection as a working miner.

About 90 nonworking miners in each of the counties in which the working miners were selected were invited to participate in the study. This number reflects about a one-third nonresponse inflation factor. Where a sample county could not provide the number required, men residing in contiguous counties were added.

Table 2 shows the populations from which the samples were selected as well as the planned and actual sample sizes. The total working miner population decreased between 1960 and 1963 and 1964, when the sample selections were made, from almost 100,000 miners in 1960 to about 80,000 at the time of selection of counties and to slightly over 64,000 at the time of examination. To accommodate the anticipated nonresponse and to provide 2,000 working and 1,000 nonworking miners, over 3,000 working miners and 1,500 nonworking miners were invited for examination. As was expected, there were some changes in the number of workers selected for the samples and the number found available at the time of examination.

As Table 2 shows, nonworking miners can be divided into two groups, "pensioners" and "unemployed." The former group was comprised of workers paying nonworking dues who had reached age 60 but not 65 by the time of examination. Most of these were already receiving retirement benefits; however, a small number were in the process of applying at the time of the study. The group removed from the sample of nonworking miners included: deceased persons, persons who moved, institutionalized persons, and persons selected initially as nonworking miners but who appeared on the working roster at the time of examination. This latter error occurred largely because of the elapsed time between the sample selection and worker contact.

Table 3 shows data on response to examination from the final sample. Response rates were much higher than anticipated, particularly among the

TABLE 2—*Population at time of sampling and at time of examination.*

Total population	Working miners	Nonworking miners	
		Unemployed	Pensioners
In 1960	98,712	(Unknown)	(Unknown)
At time of selection of county	77,463	9,162	6,964
At time of examination	64,443	(Unknown)	(Unknown)
Planned Sample	3,122	840	713
Changes:			
Decrease in employment, mines too small	7		
Nonparticipating mines [a]	350		
Removed from sample [b]	14	85	71
Total	371	85	71
Actual Sample	2,751	755	642

[a] Owners refused; miners on strike; mines closed or no longer eligible.
[b] Miners selected in sample no longer were eligible when examinations were offered.

TABLE 3—*Participants responding and not responding for examination.*

Response for examination	Working miners		Nonworking miners			
			Unemployed		Pensioners	
	Number	Percent	Number	Percent	Number	Percent
Examined	2,549	92.7	617	81.6	574	89.4
Not Examined:						
Ill, injured	18	.7	16	2.1	15	2.3
Refused	119	4.3	38	5.2	32	5.0
Unable to contact	6	.2	24	3.2	9	1.4
Other	59	2.1	60	7.9	12	1.9
Total	202	7.3	138	18.4	68	10.6
Total	2,751	100.0	755	100.0	642	100.0

working miners, so that a total of 3,740 men was examined rather than the 3,000 initially planned for.

Table 4 shows the actual sample and examination done for the counties that fell in the sample from each of the 17 strata. In Harlan County, Ky., all working miners invited actually accepted, and in Barbour-Upshur Counties, W. Va., all pensioners invited accepted examination. In two counties, unemployed coal miner participation was below 70 percent—Wyoming, West Virginia, and Hopkins, Ky.

The plan of study of coal miners' pneumoconiosis in the two Appalachian communities of Richwood and Mullens, W. Va., is detailed in Section IV.

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Table 4—*Number of participants examined by stratum.*

Stratum—County	Working miners		Nonworking miners			
			Unemployed		Pensioners	
	Actual sample	Number examined	Actual sample	Number examined	Actual sample	Number examined
1. Kanawha, W. Va.	167	159	75	53	12	10
2. Wyoming, W. Va.	169	137	72	46	17	14
3. Logan, W. Va.	185	178	63	56	17	16
4. McDowell, W. Va.	162	156	57	51	24	23
5. Letcher, Ky.	193	176	58	52	21	20
6. Buchanan, Va.	131	118	53	44	21	17
7. Wise-Lee, Va.	175	168	26	21	44	38
8. Harlan, Ky.	83	83	38	37	42	39
9. Jefferson-Shelby, Ala.	149	146	32	24	61	49
10. Hopkins, Ky.	159	142	48	32	31	24
11. Barbour-Upshur, W. Va.	162	160	42	37	50	50
12. Preston, W. Va.	178	148	50	42	33	29
13. Fayette-Bedford, Pa.	168	164	15	14	86	73
14. Allegheny, Pa.-Brooke, W. Va.	172	164	18	15	58	54
15. Greene, Pa.	162	157	41	37	62	59
16. Washington, Pa.	168	157	26	25	46	44
17. Raleigh, W. Va.	168	136	41	31	19	15
Total	2,751	2,549	755	617	642	574
Percent Examined		93		82		89

SECTION III

Prevalence of Coal Miners' Pneumoconiosis in Appalachian Bituminous Coal Miners

Prevalence of Coal Miners' Pneumoconiosis in Appalachian Bituminous Coal Miners

WILLIAM S. LAINHART, M.D.

Between January 15, 1963, and January 14, 1965, 2,549 working miners of an estimated 64,000 miners employed in bituminous coal mines with more than 15 regularly employed underground workers in the Appalachian region, and 1,191 nonworking miners, from an overall of 16,000 nonworking (retired, disabled, and temporarily out-of-work)* miners, were examined in mobile equipment usually stationed at or near the mine portal. The examinations were usually performed on the miners' own time, before or after regular work shifts. The miners were queried primarily about chest illness and symptomatology. A history of their total work experience both in and out of coal mining was recorded and a smoking history was taken. The actual questionnaire used is reproduced in Appendix 1. The numbers, percentages, and means presented in this section are based on the actual number of workers examined in the Appalachian region.

DEMOGRAPHIC CHARACTERISTICS OF POPULATION STUDIED

Demographic parameters measured in this population of Appalachian coal miners were age, height, weight, and ethnic composition.

Age

The arithmetic mean age of the working miners was 46.5 years. The nonworking miners were more than 10 years older, averaging about 57.2 years (Table 5). About 38 percent of the working miners were in the 45 to 54 age group whereas 20.1 percent of the working and 76.5 percent of the nonworking miners were over 55 years of age (Figure 9, Table 5). Less than 1.0 percent of the working miners were older than 65 and less than 1.0 percent of the nonworking miners were younger than 35.

* As explained in Section II, there were a number of nonworking miners who were not included in the sample for various reasons, the chief one being nonunion membership at the time of selection of the sample.

Weight and Height

Height and weight distributions were similar for the two groups although the average nonworking miner was slightly shorter and weighed less than the working miner. Over half of the working and nonworking miners were between 170 and 179 centimeters (66.9 and 70.5 inches) in height. There was a noticeable tendency for the weight of both groups to cluster within the 60- to 89-kilogram range (132 to 196 pounds): over 75 percent of both groups of miners fell within this range.

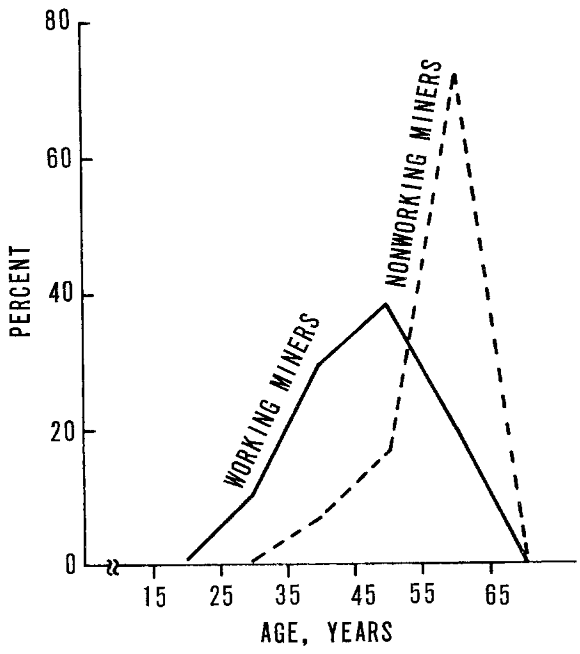

Figure 9.—Age of working and nonworking miners

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TABLE 5—*Age of working and nonworking miners.*

Age group, years	Working miners		Nonworking miners	
	Number	Percent	Number	Percent
15 through 24	41	1.6	...	...
25 through 34	267	10.5	3	0.3
35 through 44	751	29.4	80	6.7
45 through 54	979	38.4	196	16.5
55 through 64	504	19.8	876	73.5
65 or more	7	.3	36	3.0
Total	2,549	100.0	1,191	100.0
Mean age	46.5 years		57.2 years	

Race

Of the working coal miners, 93.8 percent were Caucasian; of the nonworking miners, 86.1 percent were Caucasian. The remainder were Negro.

PRESENT OCCUPATION

The occupations of the men studied were divided into two major categories, underground and surface operations, and these were further broken down by specific activity (Tables 6 and 7). The job title of the miner at the time of the examination was considered his "present occupation," regardless of how long he had worked under that title. On the basis of this, 83.5 percent were classified as present underground miners and 16.5 percent as present surface workers. Exact breakdown by activity can be seen in Table 8.

PRINCIPAL OCCUPATION

"Principal occupation," as opposed to "present occupation," is that occupation to which the worker has devoted the most number of years. Thus, a worker may have spent most of his working years in dusty face activities, but for reasons of seniority, age, partial disability, and so forth, been presently reassigned to less strenuous surface work. Again, principal occupations were grouped as were the present occupations, and in this category, 84.5 percent worked underground and 15.5 percent at the surface (Table 8 and Figure 10). The higher percentage of workers claiming underground work as principal rather than present occupation may be indicative of the shift from manual labor to more mechanization in the mining industry. Thus, 42 percent reported face activities as their principal occupation whereas only 33.2 percent reported face activities as a present occupation.

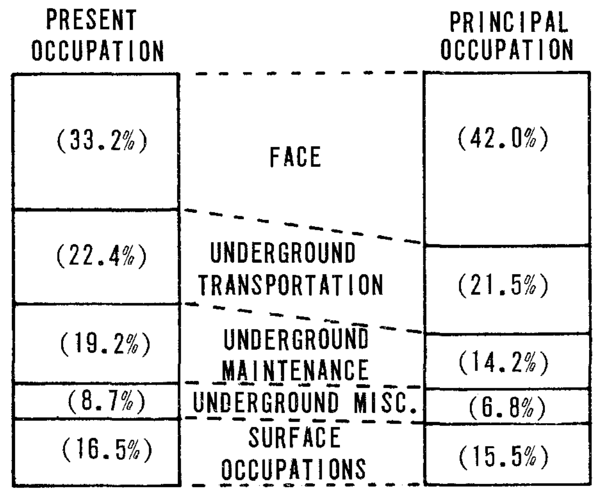

Figure 10.—Present and principal occupations of working miners

About 75 percent of the working miners in each broad classification of coal mining activities reported the same present and principal occupation (Tables 9, Figures 10 and 11). Of workers with principal occupations underground, 97.3 percent reported their present occupation to be in the same category. Conversely, only 2.7 percent reported present surface activities when their principal work had been underground. Of those whose principal work history involved surface activities, 92.2 percent were found working at the surface; 7.8 percent reported underground occupations as the present job.

The prevalence of underground mining experience was especially striking among the nonworking

Table 6—*Classification of underground coal mining occupations.*

Occupations	
Face	*Maintenance*
Development work in coal	Timber repairmen (main line), waste timber haulers
Development work in rock	Bonders, trackmen and helpers
Cutting machine operators and helpers	Electricians and helpers, wiremen, mechanics, general repairmen
Continuous mining machine operators and helpers	Pipemen and helpers, pumpmen
Hand loaders, coal diggers, general miners	Supply and material men
Timbermen and helpers	Rock dusters
Roof bolters and helpers	Ventilation men, brattice men, sprinklers, masons
Loading machine operators and helpers, duckbill operators	Cleanup men (laborers), rail recovery men
Miscellaneous drillers and helpers, hand and machine conveyor men, conveyor helpers, shotfirers and blasters, slate workers	Miscellaneous greasers, bit grinders, oilers, shopmen, shaft men
Transportation	*Miscellaneous*
Motormen and brakemen	Superintendents, assistant foremen, section bosses, grade foremen
Beltmen	Powdermen
Boom boys	Engineers, rodmen, transitmen
Rope riders	Fire bosses, mine examiners
Couplers, car nippers, sproggers, car droppers	Safety directors
Car dumpers, shaft and slope attendants	Dispatchers, maintenance foremen
Drivers (pony), muleskinners	Miscellaneous production engineers, maintenance clerks
Shuttle car operators	
Miscellaneous tool nippers, material men, cage tenders, hoistmen, trappers	

TABLE 7—*Classification of surface coal mining occupations*

Occupations	
Transportation	*Tipple (including preparation and cleaning plants)*
Hoistmen, aerial tram operators	Mine car dumpers
Shaft, plane, and slope attendants	Rail car droppers and trimmers
Motormen and brakemen	Car couplers, rope tenders, switchmen
Conveyor attendants	Greasers, oilers, mechanics (tipple machinery), electricians
Coal truck drivers, tractor operators, payloader operators	Tipple operators, crushers, screeners
Car oilers	Weighmen and check takers
Teamsters	Bony pickers, slate pickers
Miscellaneous barnmen, switchmen	Binmen, car loaders
	Miscellaneous cleanup men, laborers, pumpers, dryer operators, truck drivers
Maintenance	*Strip Mining*
Electricians, linemen	Bulldozer operators
Mechanics, general repairmen	Power shovel operators and helpers
Carpenters and helpers	Truck drivers
Welders	Drillers and helpers
Blacksmiths and helpers	Scraper operators
Machinists	Shotfirers
Plumbers, pipemen and helpers	Owner and operator of strip mine
Miscellaneous painters, car repairmen, firemen, laborers, pumpmen, bit grinders, cable riggers, rope men, battery shop men, shopmen, bull-gang laborer (general)	Miscellaneous coal cleaner (hand work or pick)
Miscellaneous	
Office and general supervisors, cashiers, clerks, telephone operators	
Lamphouse men, fan men	
Samplers, assayers, chemists	
Engineers, assistants, rodmen, transitmen	
Outside foremen, preparation foremen, tipple foremen, maintenance foremen, janitors, guards, storekeepers, sand dryers, watchmen, wash house attendants, delivery truck drivers, timber cutters	

TABLE 8—*Present and principal occupation of working miners*

Occupation	Present occupation		Principal occupation	
	Number	Percent	Number	Percent
Underground:				
Face	844	33.2	1,068	42.0
Transportation	570	22.4	548	21.5
Maintenance	488	19.2	360	14.2
Miscellaneous	222	8.7	174	6.8
Total	2,124	83.5	2,150	84.5
Surface:				
Transportation	50	2.0	47	1.8
Maintenance	122	4.8	107	4.2
Tipple work	172	6.7	162	6.4
Strip mining	7	.3	67	2.6
Miscellaneous	70	2.7	12	.5
Total	421	16.5	395	15.5
Total known	2,545	....	2,545	....
Unknown occupational history	4	....	4	....

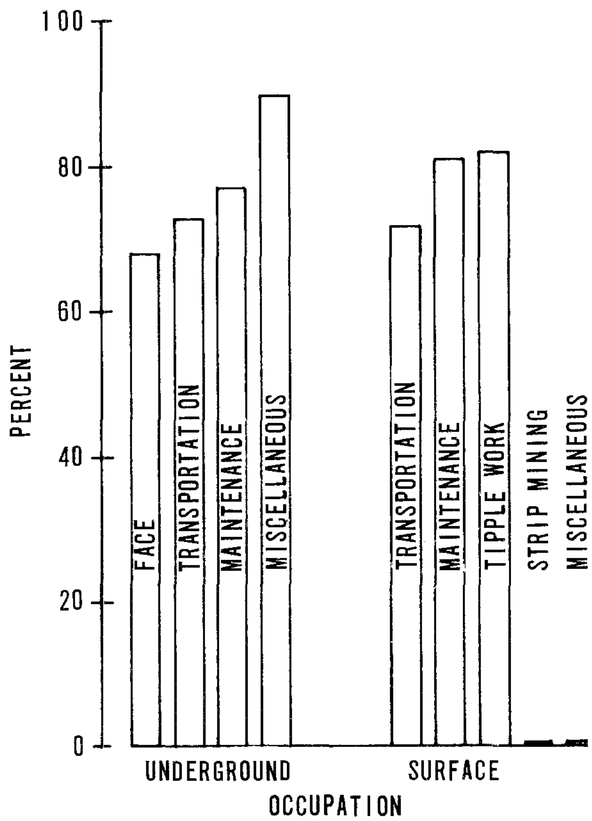

Figure 11.—Working miners with same present and principal occupation

miners where approximately 90 percent were listed as having worked principally underground (Table 10). This primarily involved activities at or near the mining face and, again, indicates the continuing shift away from manual coal mining.

YEARS IN COAL MINING OCCUPATIONS

The mean number of years in coal mining for all working miners was 24.5 years (Table 11). Underground workers averaged over 4 years more in the coal mining industry (mean: 25.2 years) than surface workers (20.8 years). Underground face and transportation employees worked slightly fewer years in the industry than maintenance and miscellaneous job holders. Surface workers in transportation, maintenance, tipple and miscellaneous jobs worked an average of over 20 years in the industry, whereas the few men classified as strip miners were relatively new to the industry. The nonworking miners had, on the whole, more general mining experience than the working miners, with a mean of 33.0 years in the industry. Former underground miners reported a longer history of coal mining than former surface workers (33.4 years as against 28.9 years).

PULMONARY MORBIDITY PATTERNS

With the use of a standardized questionnaire approved by the Medical Research Council of

TABLE 9—*Present and principal occupations of working miners.*

Principal occupation	Total	Present occupation: Underground: Face	Underground: Trans-portation	Underground: Mainte-nance	Underground: Miscel-laneous	Underground: Total	Surface: Trans-portation	Surface: Mainte-nance	Surface: Tipple work	Surface: Strip mining	Surface: Miscel-laneous	Surface: Total
Underground:												
Face	1,068	733	139	138	37	1,047	3	5	11	1	1	21
		(68.6)[a]	(13.0)	(12.9)	(3.5)	(98.0)	(0.3)	(0.5)	(1.0)	(0.1)	(0.1)	(2.0)
Transportation	548	70	399	47	12	528	1	9	8	0	2	20
		(12.8)	(72.8)	(8.5)	(2.2)	(96.3)	(0.2)	(1.6)	(1.5)	(0.0)	(0.4)	(3.7)
Maintenance	360	28	25	278	14	345	0	11	2	0	2	15
		(7.8)	(6.9)	(77.2)	(3.9)	(95.8)	(0.0)	(3.0)	(0.6)	(0.0)	(0.6)	(4.2)
Miscellaneous	174	6	0	11	156	173	0	0	1	0	0	1
		(3.4)	(0.0)	(6.3)	(89.7)	(99.4)	(0.0)	(0.0)	(0.6)	(0.0)	(0.0)	(0.6)
Total	2,150	837	563	474	219	2,093	4	25	22	1	5	57
		(38.9)	(26.2)	(22.0)	(10.2)	(97.3)	(0.2)	(1.2)	(1.0)	(0.1)	(0.2)	(2.7)
Surface:												
Transportation	47	0	1	1	0	2	34	4	6	0	1	45
		(0.0)	(2.1)	(2.1)	(0.0)	(4.2)	(72.4)	(8.5)	(12.8)	(0.0)	(2.1)	(95.8)
Maintenance	107	3	1	7	0	11	3	87	4	0	2	96
		(2.8)	(0.9)	(6.6)	(0.0)	(10.3)	(2.8)	(81.3)	(3.7)	(0.0)	(1.9)	(89.7)
Tipple work	162	3	3	5	1	12	7	4	133	0	6	150
		(1.9)	(1.9)	(3.0)	(0.6)	(7.4)	(4.3)	(2.5)	(82.1)	(0.0)	(3.7)	(92.6)
Strip mining	67	1	2	1	1	5	0	1	5	0	56	62
		(1.5)	(3.0)	(1.5)	(1.5)	(7.5)	(0.0)	(1.5)	(7.5)	(0.0)	(83.5)	(92.5)
Miscellaneous	12	0	0	0	1	1	2	1	2	6	0	11
		(0.0)	(0.0)	(0.0)	(8.3)	(8.3)	(16.7)	(8.3)	(16.7)	(50.0)	(0.0)	(91.7)
Total	395	7	7	14	3	31	46	97	150	6	65	364
		(1.8)	(1.8)	(3.4)	(0.8)	(7.8)	(11.6)	(24.6)	(38.0)	(1.5)	16.5)	(92.2)
Total	2,545	844	570	488	222	2,124	50	122	172	7	70	421
Unknown occupational history	4	...	...	...	...	...	...	...	...	...	...	...

[a] Percentage.

Great Britain's Committee on Aetiology of Bronchitis,[1] each miner was asked specific questions geared to determining any symptoms that could be identified with chronic lung disease (see Appendix 1 for actual questionnaire). Although often difficult to define and differentiate, symptoms of different chronic lung diseases (such as emphysema, bronchitis, "miners' asthma," tuberculosis, and recurring pneumonitis) as well as specific dust diseasees (which have long been associated with the mining industry) can also be found in nonmining populations. Morbidity patterns or chest symptoms and disorders among coal miners must be considered in reference to patterns seen in the population at large.

Questions were asked of each participant about his history of specific health conditions such as pneumonia, asthma, pleurisy, bronchitis, tuberculosis, "dust on the lungs," and heart trouble as well as any other nonspecified chest conditions in an attempt to outline morbidity patterns of chronic chest disease among Appalachian coal miners. The phrase "dust on the lungs" appeared on the questionnaire instead of "pneumoconiosis" because of its popular usage among miners. No attempt was made to ascertain how a diagnosis was made; the miner was to answer "yes" or "no" to whether he had or had been told he had any of the conditions (Tables 12 and 13, Figure 12).

Conditions most commonly reported by working miners were pneumonia (24.0 percent) and pleurisy (10.5 percent). Between 5 and 10 percent reported

TABLE 10—*Principal occupation of nonworking miners.*

Occupation	Number	Percent
Underground:		
Face	675	57.3
Transportation	246	20.9
Maintenance	126	10.7
Miscellaneous	7	.6
Total	1,054	89.5
Surface:		
Transportation	9	.8
Maintenance	41	3.5
Tipple work	63	5.4
Strip mining	6	.5
Miscellaneous	4	.3
Total	123	10.5
Total	1,177	100.0
Unknown occupational history	14	....

TABLE 11—*Mean years in coal mining by principal occupation.*

Principal occupation	Working miners		Nonworking miners	
	Number	Mean years	Number	Mean years
Underground:				
Face	1,068	25.0	675	33.1
Transportation	548	24.2	246	35.0
Maintenance	360	25.5	126	32.6
Miscellaneous	174	28.5	7	(*) [a]
Total	2,150	25.2	1,054	33.4
Surface:				
Transportation	47	22.9	9	(*)
Maintenance	107	20.0	41	29.6
Tipple work	162	20.8	63	29.2
Strip mining	67	9.2	4	(*)
Miscellaneous	12	22.9	6	(*)
Total	395	20.8	123	28.9
Total	2,545	24.5	1,177	33.0
Unknown occupational history	4	....	14	....

[a] Asterisk indicates less than 10 persons in grouping.

TABLE 12—*History of specified chest conditions by age*
(By number)

Medical history	Response	Age: Less than 35	35–44	45–54	55–64	65 or more	Total known	Unknown history
Working miners:								
Pneumonia	Yes	63	170	246	131	1	611	....
	No	244	580	730	373	6	1,933	5
Asthma	Yes	12	38	57	44	0	151	....
	No	295	709	912	458	7	2,387	11
Pleurisy	Yes	25	55	110	76	1	267	....
	No	282	692	806	427	6	2,273	9
Bronchitis	Yes	20	36	73	45	0	174	....
	No	286	713	901	459	7	2,366	9
Tuberculosis	Yes	0	3	9	6	0	18	....
	No	307	747	966	498	7	2,525	6
Dust on the lungs	Yes	4	37	85	71	1	198	....
	No	302	712	888	433	6	2,341	10
Heart trouble	Yes	9	25	59	49	1	143	....
	No	297	724	912	454	6	2,393	13
Other chest trouble	Yes	21	35	55	28	2	141	....
	No	283	709	916	475	5	2,388	20
Nonworking miners:								
Pneumonia	Yes	1	20	57	274	7	359	....
	No	2	56	133	595	29	815	17
Asthma	Yes	0	3	24	136	3	166	....
	No	3	73	166	732	33	1,007	18
Pleurisy	Yes	0	14	24	128	3	169	....
	No	3	62	166	741	33	1,005	17
Bronchitis	Yes	0	7	34	126	2	169	....
	No	3	69	157	740	34	1,003	19
Tuberculosis	Yes	0	0	6	20	2	28	....
	No	3	76	184	848	34	1,145	18
Dust on the lungs	Yes	0	9	77	298	10	394	....
	No	3	67	113	572	26	781	16
Heart trouble	Yes	0	6	36	240	7	289	....
	No	3	70	154	625	29	881	21
Other chest trouble	Yes	2	13	21	113	7	156	....
	No	1	63	170	751	29	1,014	21

asthma, bronchitis, "dust on the lungs," heart trouble, or other chest conditions. Less than 1.0 percent reported a history of tuberculosis. The nonworking miners, partly because they were (on the average) older, more frequently reported a history of all conditions. The most striking difference was that one-third of the total nonworking men gave a history of "dust on the lungs" compared with 7.8 percent for the working miners.

The number of chest conditions reported increased with age except in the general category of "other chest trouble." Asthma, pleurisy, bronchitis, tuberculosis, "dust on the lungs," and heart trouble were reported more often in the older working miners. In general, the nonworking miners reported more of all the respiratory symptoms and conditions than did the working miners. The relationship between age and history of disease is not striking in the nonworking miners with the exception of "dust on the lungs," heart trouble, and possibly asthma and bronchitis.

RESPIRATORY SYMPTOMS

Persistent Productive Cough

Persistent productive cough characteristic of chronic bronchitis has been considered an important disorder in the mining population in various parts of the world.[2–5] Persistent productive cough is de-

TABLE 13—*History of specified chest conditions by age.*
(By percent positive replies)

Medical history	Age: Less than 35	35–44	45–54	55–64	65 or more	Total
Working miners:						
Pneumonia	20.5	22.7	25.2	26.0	(*) [a]	24.0
Asthma	3.9	5.1	5.8	8.8	(*)	5.9
Pleurisy	8.1	7.4	11.3	15.1	(*)	10.5
Bronchitis	6.5	4.8	7.6	8.9	(*)	6.9
Tuberculosis	0	.4	.9	1.2	(*)	.7
Dust on the lungs	1.3	4.9	8.7	14.1	(*)	7.8
Heart trouble	2.9	3.3	6.1	9.7	(*)	5.6
Other chest trouble	6.9	4.7	5.7	5.6	(*)	5.6
Nonworking miners:						
Pneumonia	(*)	26.3	30.0	31.5	19.4	30.6
Asthma	(*)	3.9	12.6	15.7	8.3	14.2
Pleurisy	(*)	18.4	12.6	14.7	8.3	14.4
Bronchitis	(*)	9.2	17.8	14.5	5.6	14.4
Tuberculosis	(*)	0	3.3	2.3	5.6	2.4
Dust on the lungs	(*)	11.8	40.5	34.3	27.8	33.5
Heart trouble	(*)	7.9	18.9	27.7	19.4	24.7
Other chest trouble	(*)	17.1	11.0	13.1	19.4	13.3

[a] Asterisk indicates less than 10 persons in age group.

fined as the presence of cough with sputum production for at least 3 months each year for at least 3 years (slight modification of definition propounded by the Medical Research Council on Aetiology of Bronchitis, Great Britain [1]). For this report, any cough that did not fulfill this time requirement or was not accompanied by any sputum production was considered less significant and designated as a "less than persistent productive cough." Almost 10 percent of the working miners and about 24 percent of the nonworking coal miners reported a persistent productive cough (Table 14). No cough or sputum was reported in 71.3 percent of the working miners and 47.8 percent of the nonworking miners.

Dyspnea

The five levels of dyspnea (shortness of breath) and the percentages reported during the preliminary investigations are indicated in Table 15. For this report, these levels are regrouped into three categories: "none" or "slight," indicating no reported dyspnea when hurrying on level ground or walking up a slight hill; "moderate," indicating dyspnea when walking on level ground with other people of the same age; and "marked and severe" when positive response was recorded to such questions as whether the miner had to stop for breath when walking at his own speed on level ground (marked) or became short of breath when washing or dressing

TABLE 14—*History of cough.*

Degree of cough	Working miners: Number	Working miners: Percent	Nonworking miners: Number	Nonworking miners: Percent
No cough or sputum	1,810	71.3	561	47.8
Less than persistent productive cough	495	19.5	333	28.4
Persistent productive cough	233	9.2	280	23.8
Total	2,538	100.0	1,174	100.0
Unknown cough history	11	....	17	....

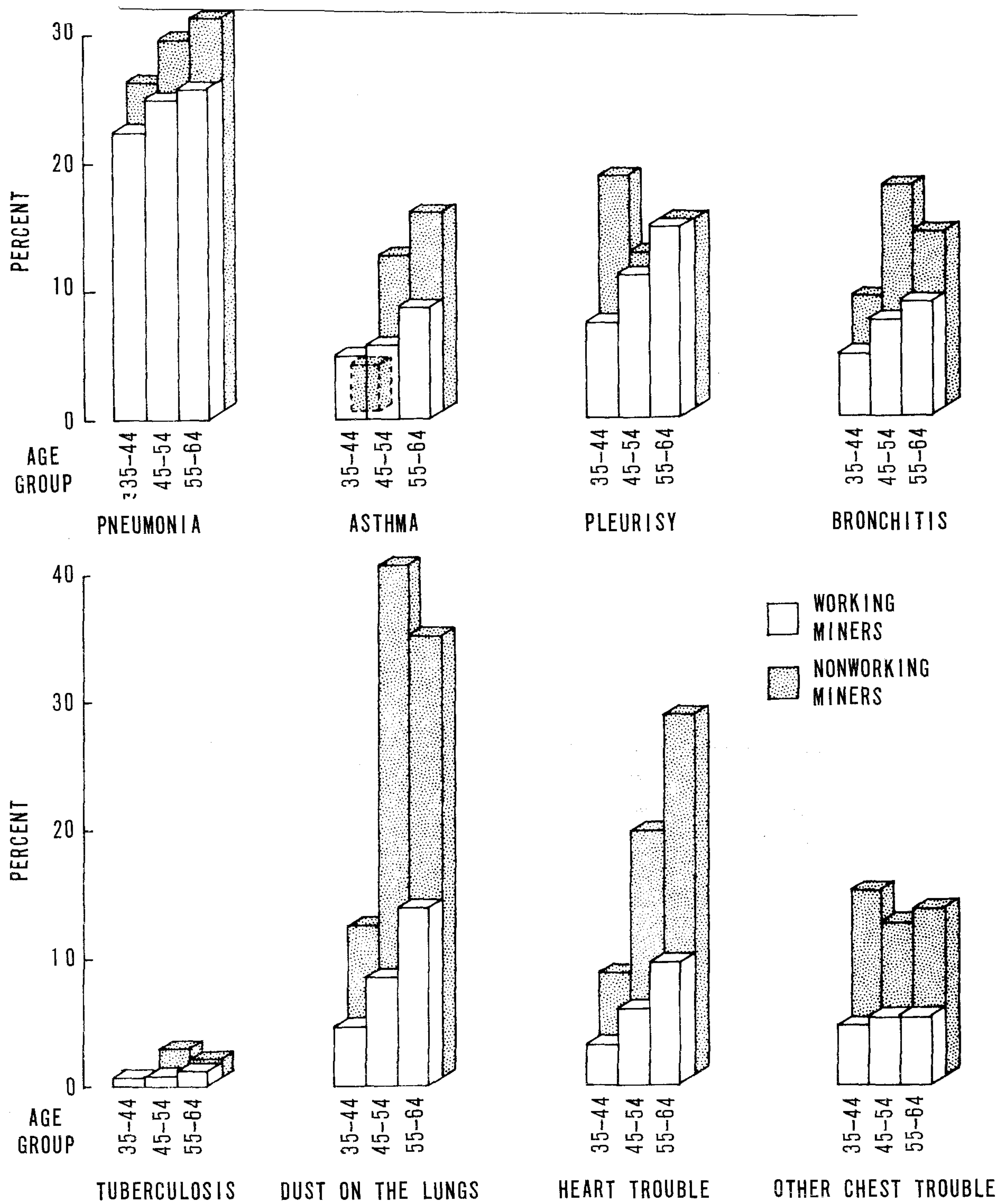

Figure 12.—History of specified chest conditions, by age, for working and nonworking miners

TABLE 15.—*History of dyspnea.*

Degree of dyspnea	Working miners		Nonworking miners	
	Number	Percent	Number	Percent
None	1,209	47.6	174	15.4
Slight	1,001	39.4	336	29.7
Moderate	239	9.4	208	18.4
Marked	62	2.5	138	12.2
Severe	28	1.1	275	24.3
Total	2,539	100.0	1,131	100.0
Disabled or unknown dyspnea history	10	....	30 [a]	....
Total	2,549	....	1,161	....

[a] Of nonworking miners, 44 disabled due to noncardiopulmonary causes.

(severe). Miners who were crippled, in a cast, or missing a limb were not considered meaningful to the dyspnea investigation and were excluded from consideration.

Nearly two-thirds (65.8 percent) of the working miners reported no persistent productive cough or dyspnea, whereas 1.1 percent reported a marked degree of both symptoms (Table 16). Varying numbers reported mixed symptoms. Fewer nonworking miners (30.9 percent) had no cough or dyspnea than working miners. A marked presence of both symptoms was reported by 15.2 percent of the men no longer mining.

The relationship between the marked and severe forms of dyspnea, age, and years underground is presented in Table 17 and Figure 13. There are marked differences in symptoms for all ages and years underground for both working and nonworking miners, with the latter showing several times as much dyspnea. From these data, it appears that dyspnea is associated more with age than with underground mining experience.

SMOKING HABITS

Part of the questionnaire (Appendix 1) included questions regarding the miners' cigarette smoking history. Well over half the working miners (60.9 percent) and almost half of the nonworking miners (47.1 percent) smoked cigarettes at the time of the interview (Table 18). Nonsmokers were those who

TABLE 16—*History of cough related to dyspnea.*

Cough	Dyspnea: None or slight		Dyspnea: Moderate		Dyspnea: Marked and severe		Total
	Number	Percent	Number	Percent	Number	Percent	
Working miners:							
No cough or sputum	1,666	65.8	110	4.3	28	1.1	1,804
Less than persistent productive cough	376	14.8	73	2.9	33	1.3	483
Persistent productive cough	161	6.4	55	2.2	29	1.1	245
Total	2,203	....	239	....	90	....	2,532
Unknown history of cough or dyspnea							17
Nonworking miners:							
No cough or sputum	349	30.9	90	8.0	101	8.9	540
Less than persistent productive cough	104	9.2	65	5.8	140	12.4	309
Persistent productive cough	56	5.0	52	4.6	172	15.2	280
Total	509	....	207	....	413	....	1,129
Unknown history of cough or dyspnea							62 [a]

[a] Of nonworking miners, 44 disabled due to noncardiopulmonary causes.

TABLE 17—*History of dyspnea by age of working and nonworking miners.*

Years underground	Degree of dyspnea	Age: Less than 35 Working	Age: Less than 35 Nonworking	Age: 35–44 Working	Age: 35–44 Nonworking	Age: 45–54 Working	Age: 45–54 Nonworking	Age: 55–64 Working	Age: 55–64 Nonworking	Age: 65 or more Working	Age: 65 or more Nonworking	Total Working	Total Nonworking
0 to 9	None or slight	190	2	155	15	107	7	48	40	...	...	500	64
	Moderate	7	...	2	3	11	3	8	10	1	...	29	16
	Marked and severe	2 (1.0)[a]	(*)[b]	1 (0.6)	1 (5.3)	1 (1.0)	2 (16.7)	4 (6.7)	21 (29.6)	(*)	(*)	9	26
	Total	199	2	158	19	119	12	60	71	2	2	538	106
10 to 19	None or slight	103	1	326	26	112	14	10	14	1	2	552	57
	Moderate	2	...	21	9	11	6	3	6	...	...	37	21
	Marked and severe	2 (1.9)	(*)	6 (1.7)	5 (12.5)	3 (2.4)	11 (35.5)	1 (7.1)	17 (45.9)	(*)	(*)	12	33
	Total	107		353	40	126	31	14	37	1	2	601	111
20 to 29	None or slight	1	...	196	4	374	27	60	56	1	5	630	92
	Moderate	...	...	29	2	40	17	10	27	...	...	79	46
	Marked and severe	(*)	...	11 (4.7)	4 (40.0)	13 (3.0)	37 (45.7)	4 (5.4)	57 (40.7)	(*)	*4	28	102
	Total	1	...	236	10	427	81	74	140	1	9	737	240
30 to 39	None or slight	...	...	1	...	253	17	167	161	...	6	421	184
	Moderate	...	...	1	...	32	7	32	68	...	3	65	78
	Marked and severe	...	...	(*)	...	15 (5.0)	29 (54.7)	15 (7.0)	151 (39.7)	...	3 (25.0)	30	183
	Total	...	...	2	...	300	53	214	380	...	12	516	445
40 or more	None or slight	...	...	...	...	...	1	100	106	3	6	103	113
	Moderate	...	...	...	...	2	...	27	44	...	3	29	47
	Marked and severe	...	...	...	...	...	(*)	12 (8.6)	68 (31.2)	(*)	1 (10.0)	12	69
	Total	...	...	...	...	2	1	139	218	3	10	144	229
	Unknown history of occupation or dyspnea or disabled	...	...	...	...	...	...	...	...	...	...	13	60[c]

[a] Percentage.
[b] Asterisk indicates less than 10 persons in grouping.
[c] Of nonworking miners, 44 disabled due to noncardiopulmonary causes.

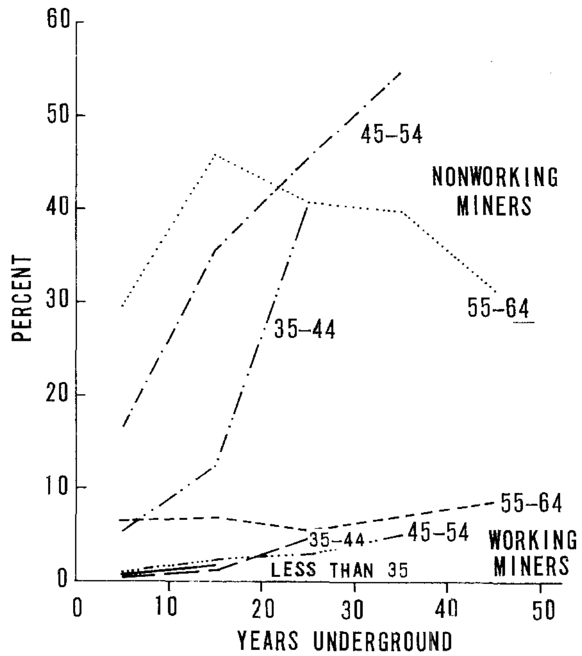

Figure 13.—Moderate, marked, and severe dyspnea by age and years underground among working and nonworking miners

indicated that they had never regularly smoked. Past smokers had formerly smoked regularly but were not smoking at the time of the interview. Because there was no consistent pattern of respiratory symptoms (dyspnea or persistent productive cough) between the nonsmokers and past smokers as defined above, these two groups of men were considered together.

The close association between smoking and respiratory symptoms has been discussed in numerous reports and also summarized.[6] Because of the additional possible association between respiratory symptoms and years underground, the miners were grouped according to smoking history and years underground and the respiratory symptoms present in each group was calculated. Persistent productive cough is related to cigarette smoking and years underground, the latter presumably including an aging factor (Table 19 and Figure 14). Between two and five times more working miners currently smoking reported persistent productive cough than those who were either former smokers or who never smoked cigarettes. The differences among nonworking miners with regard to smoking and cough are also striking with these men showing more cough than their working counterparts.

A similar picture prevails when the presence of marked and severe dyspnea is considered (Table 20 and Figure 15). The prevalence of dyspnea increases progressively with years underground, but there is also more dyspnea among cigarette smokers than among nonsmokers or past smokers. The number of nonworking miners with the more severe forms of dyspnea is much greater than that of working miners. The association between years underground and dyspnea is not as striking in the nonworking miners, but dyspnea did increase with cigarette smoking.

TABLE 18—*History of cigarette smoking*

Smoking status	Working miners		Nonworking miners	
	Number	Percent	Number	Percent
Nonsmokers	498	19.7	290	24.7
Past smokers	493	19.4	331	28.1
Present smokers	1,544	60.9	552	47.1
Total	2,535	...	1,173	...
Unknown cigarette smoking history	14	...	18	...
Present smokers:				
0 to 19 cigarettes per day	596	38.6	250	45.3
20 to 39 cigarettes per day	849	55.0	277	50.2
40 or more cigarettes per day	97	6.3	23	4.2
Unknown cigarettes per day	2	.1	2	.3
Total	1,544	...	552	...

TABLE 19—*History of cough by smoking habit and underground experience among working and nonworking miners*

Years underground	Degree of cough	Nonsmokers and past smokers		Present smokers		Total	
		Working	Nonworking	Working	Nonworking	Working	Nonworking
0 to 9	None	182	47	233	28	415	75
	<Persistent	22	6	57	10	79	16
	Persistent	5 (2.3)[a]	4 (7.0)	35 (10.8)	12 (24.0)	40	16
	Total	209	57	325	50	534	107
10 to 19	None	177	29	297	27	474	56
	<Persistent	20	15	74	28	94	43
	Persistent	3 (1.5)	6 (12.0)	28 (7.0)	17 (23.6)	31	23
	Total	200	50	399	72	599	122
20 to 29	None	209	79	286	45	495	124
	<Persistent	41	27	113	33	154	60
	Persistent	16 (6.0)	14 (11.7)	74 (15.6)	57 (42.2)	90	71
	Total	266	120	473	135	739	255
30 to 39	None	187	131	141	55	328	186
	<Persistent	34	67	89	71	123	138
	Persistent	16 (6.7)	58 (22.7)	45 (16.4)	72 (36.4)	61	130
	Total	237	256	275	198	512	454
40 or more	None	57	91	30	28	87	119
	<Persistent	14	29	19	31	33	60
	Persistent	4 (5.3)	16 (11.8)	18 (26.9)	37 (38.6)	22	53
	Total	75	136	67	96	142	232
Unknown occupational, smoking, or cough history						23	21

[a] Percentage.

ROENTGENOLOGIC STUDY

Roentgenologic Technique

A 14- by 17-inch chest roentgenogram was taken of 2,529 of the 2,549 present coal miners and 1,178 of 1,191 participating nonworking miners. The roentgenograms were taken at 72 inches with the use of a 200-milliampere mobile unit equipped with a phototimer. The miner was placed in a posterior-anterior position. Exposed roentgenograms were developed in the unit, usually at the mine site, and immediately screened by the team physician. In the event a roentgenogram was considered to be technically unsatisfactory, the miner was contacted and requested to return for a repeat roentgenogram. All films were then sent to the Occupational Health Research and Training Facility in Cincinnati for recording and distribution to the panel of radiological consultants.* Each roentgenogram was read independently without knowledge of the occupational history by the three radiologists using the U.S. Public Health Service modification of the radiological classification of the pneumoconioses (Figure 16). Where disagreements in reading were noted, the radiological consultants attended periodic conferences to assign consensus readings; otherwise, a consensus was assigned on the basis of three original

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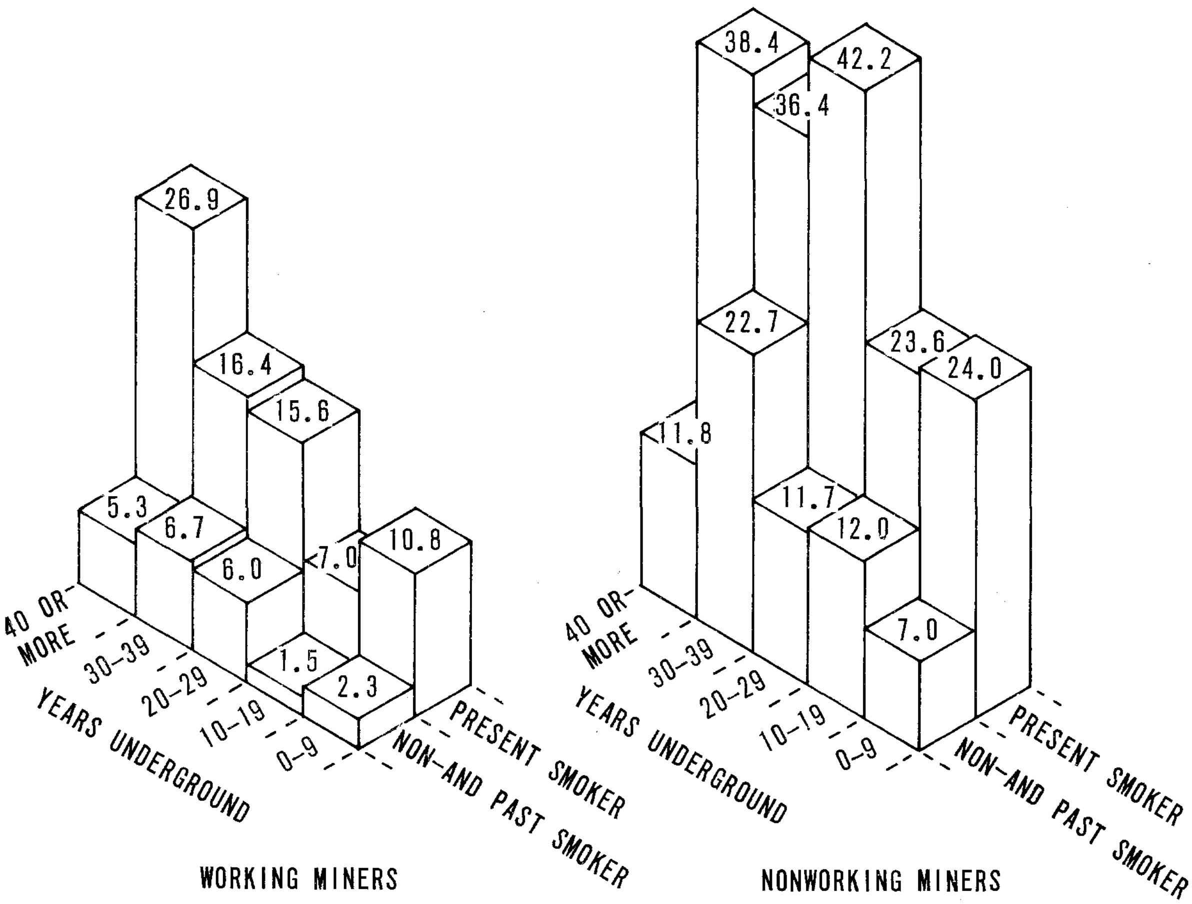

Figure 14.—Persistent productive cough by years underground and cigarette smoking habits among working and nonworking miners

readings. A roentgenogram was classified as negative for pneumoconiosis when there was no radiographic evidence of this disease in the lung fields. Suspected pneumoconiosis included shadows that might have been pneumoconiotic in origin but that were of insufficient number or extent to be included in one of the categories classifying the small opacities. Simple pneumoconiosis included only small opacities (up to and including 1 centimeter in diameter) in an area of the lung equivalent to or greater than the second and third anterior rib interspaces of either side of the chest. A roentgenogram was classified as showing complicated pneumoconiosis when there were one or more large opacities (greater than 1 centimeter in diameter), regardless of the background of small opacities. A roentgenogram with a classification of either simple or complicated pneumoconiosis was considered "definite" pneumoconiosis, as opposed to one classified as "suspect" pneumoconiosis.

A special study was conducted to compare the interpretations of British readers of these roentgenograms of American bituminous coal miners with those of American readers.

To provide a measure of the "across-the-Atlantic" comparability of readings of roentgenograms of American coal miners, a randomly selected series of roentgenograms was sent to Great Britain to be read by National Coal Board film readers, utilizing the method presently being employed by that organization.[7] The study was coordinated by Mr. F. D. K. Liddell, then Head, Medical Statistics Branch, National Coal Board, who prepared the following summary (slightly modified):

In the Autumn of 1965, a series of 1,800 single films of American coal miners was assessed for

TABLE 20—*History of dyspnea by smoking habit and underground experience among working and nonworking miners*

Years underground	Degree of dyspnea	Nonsmokers and past smokers		Present smokers		Total	
		Working	Nonworking	Working	Nonworking	Working	Nonworking
0 to 9	None or slight	197	34	302	30	499	64
	Moderate	9	10	20	6	29	16
	Marked and severe	3 (1.4) [a]	12 (21.4)	5 (1.5)	14 (28.0)	8	26
	Total	209	56	327	50	536	106
10 to 19	None or slight	185	26	366	31	551	57
	Moderate	10	5	26	16	36	21
	Marked and severe	5 (2.5)	13 (29.5)	7 (1.8)	20 (30.3)	12	33
	Total	200	44	399	67	599	111
20 to 29	None or slight	234	46	395	46	629	92
	Moderate	23	27	55	19	78	46
	Marked and severe	6 (2.3)	39 (34.8)	22 (4.7)	63 (49.2)	28	102
	Total	263	112	472	128	735	240
30 to 39	None or slight	199	117	222	66	421	183
	Moderate	32	41	33	36	65	77
	Marked and severe	8 (3.3)	90 (36.4)	22 (8.0)	92 (47.4)	30	182
	Total	239	248	277	194	516	442
40 or more	None or slight	60	71	43	42	103	113
	Moderate	12	27	16	20	28	47
	Marked and severe	3 (4.0)	37 (27.4)	8 (11.9)	32 (34.4)	11	69
	Total	75	135	67	94	142	229
Unknown occupational, smoking, or dyspnea history						21	63 [b]

[a] Percentage.
[b] Of nonworking miners, 44 disabled due to noncardiopulmonary causes.

pneumoconiosis by six National Coal Board film readers. Although the films had already been assessed by an American concensus of readers using the previously described method, these readings were not available to the British readers.

There was found to be a fair measure of agreement between American and British reading on the proportions of subjects (a) who showed no evidence of pneumoconiosis and (b) who showed evidence of undoubted disease.

Nevertheless, there were substantial differences betwen American and British reading in categorization. Information was obtained whereby the distribution by category according to American consensus, of any population, could be converted to the corresponding distribution that might be obtained by British reading, should the same patterns apply.

In more detailed consideration, it was found that:

(1) British readings of 0/– ("barn-door" normal) were given only to films that the American consensus considered normal.

(2) British reading of all films read by the consensus of Americans as normal was, on the average, at the same level. There were, however, considerable differences in level between the various British readers.

(3) Films placed by the American consensus as Z or 1 were read by the British at a somewhat lower level.

(4) Films assessed by the Americans as showing

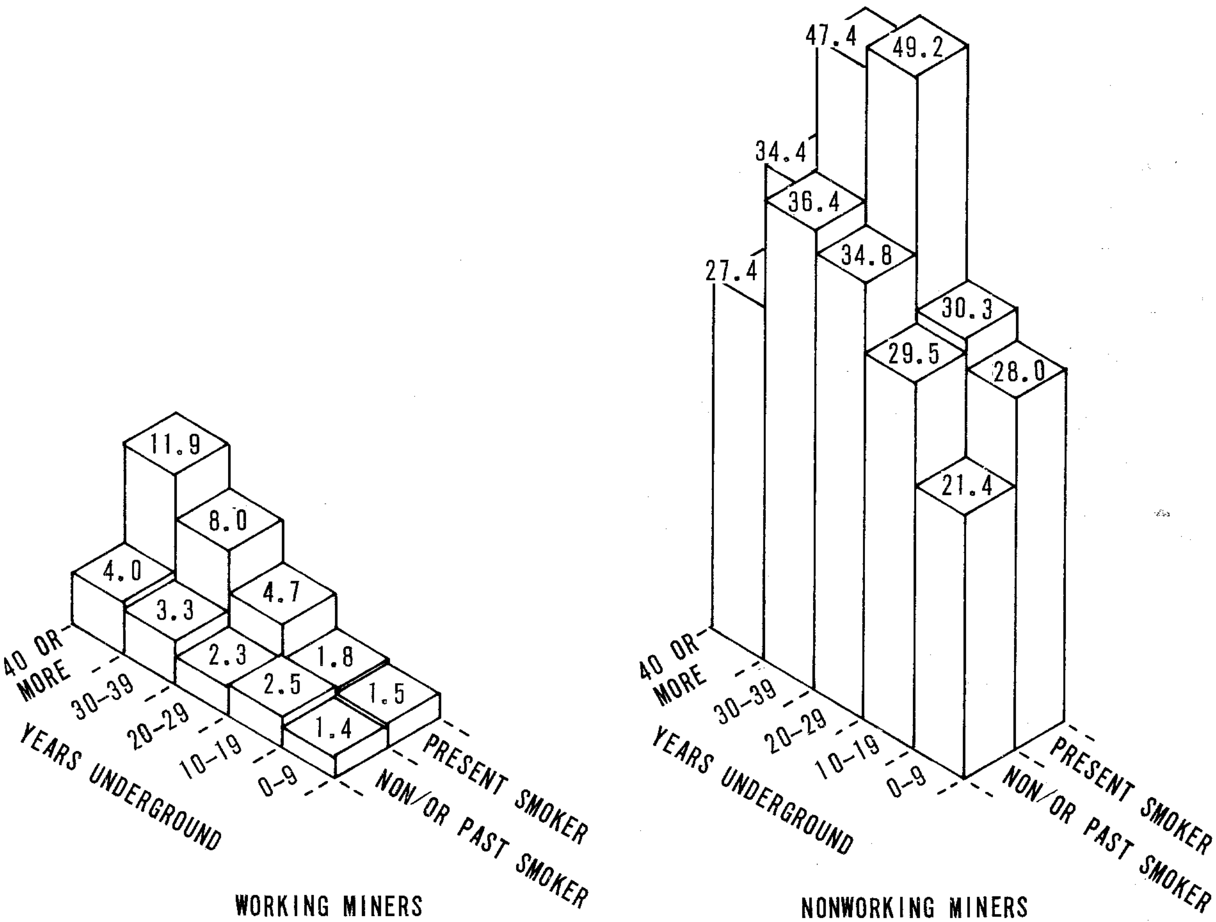

Figure 15.—Marked and severe dyspnea by years underground and cigarette smoking habits among working and nonworking miners

more disease than in 3, above, were generally assessed as nonnormal by the British, but again at lower levels.

Roentgenologic Findings

Detailed readings of pneumoconiosis in chest roentgenograms of working and nonworking miners are shown in Table 21. Definite roentgenologic evidence of pneumoconiosis was found in 9.8 percent of the presently working coal miners and 18.2 percent of the nonworking miners. Of the working miners, 6.8 percent showed evidence of simple pneumoconiosis and 3.0 percent, the complicated disease; equivalent percentages for the nonworking miners were 9.2 and 9.0.

In the medical histories reported in the subsection on pulmonary morbidity patterns, 7.8 percent of the working miners and 33.5 percent of the nonworking miners reported a history of "dust on the lungs." Of the 197 working miners and 393 nonworking miners who reported this history, over one-half (53.8 percent and 53.2 percent) had no roentgenographic indication of nodulation consistent with a diagnosis of pneumoconiosis (Table 22 and Figure 17). Almost 40 percent of those who reported a history of "dust on the lungs" had roentgenographic readings consistent with pneumoconiosis. On the other hand, over 7 percent of the roentgenograms taken of both working and nonworking miners with no history of "dust on the lungs" showed definite (either simple or complicated) pneumoconiosis.

Among the working miners, roentgenographic evidence of pneumoconiosis was found primarily in underground workers (Table 23 and Figure 18): 11.2 percent of those principally employed

	FILM QUALITY		NO PNEUMO-CONIOSIS	SUSPECT	PNEUMOCONIOSIS					
TYPE OF OPACITY					SMALL OPACITIES			LARGE OPACITIES*		
QUANTITATIVE FEATURES	UNSAT. FILM	POOR FILM	O	Z	1	2	3	A	B	C
QUALITATIVE FEATURES					p q r	p q r	p q r			

ADDITIONAL SYMBOLS	ax	ca	cn	co	cv	di	em	es	hi	pl	px	rl	tb	tba	nt	np

FILM QUALITY	UNSATISFACTORY FILM — IMPOSSIBLE TO READ POOR FILM - DETAILED CLASSIFICATION DIFFICULT	
NO PNEUMO-CONIOSIS	O - NO RADIOGRAPHIC EVIDENCE OF PNEUMOCONIOSIS IN LUNG FIELDS.	
SUSPECT OPACITIES	Z - SHADOWS WHICH MAY BE PNEUMOCONIOTIC BUT WHICH ARE INSUFFICIENT FOR THE FILM TO BE PLACED IN ONE OF THE CATEGORIES CLASSIFYING THE SMALL OPACITIES.	
	PNEUMOCONIOSIS	
SMALL OPACITIES	THE CATEGORIZATION DEPENDS ON THE EXTENT AND PROFUSION OF THE OPACITIES: 1. A NUMBER OF OPACITIES IN AN AREA EQUIVALENT TO AT LEAST THE SECOND AND THIRD ANTERIOR RIB SPACES OF EITHER SIDE, AND AT THE MOST, NOT GREATER THAN ONE THIRD OF THE TWO LUNG FIELDS COMBINED. 2. OPACITIES MORE DIFFUSE THAN IN CATEGORY 1 WHICH MAY BE DISTRIBUTED OVER THE WHOLE OR NEARLY THE WHOLE OF THE LUNG FIELDS 3. VERY NUMEROUS OPACITIES DISTRIBUTED OVER THE WHOLE, OR NEARLY THE WHOLE OF THE LUNG FIELDS	THESE ARE CLASSIFIED ACCORDING TO THE GREATEST DIAMETER OF THE PREDOMINANT OPACITIES AND DENOTED BY THE FOLLOWING SYMBOLS: p - GREATEST DIAMETER UP TO AND INCLUDING 1.5 mm q - GREATEST DIAMETER FROM 1.5 mm UP TO AND INCLUDING 3 mm. r - GREATEST DIAMETER FROM 3 mm UP TO AND INCLUDING 1 cm
LARGE OPACITIES	A - AN OPACITY HAVING A GREATEST DIAMETER EXCEEDING 1 cm AND UP TO AND INCLUDING 5 cm OR SEVERAL OPACITIES EACH GREATER THAN 1 cm, THE SUM OF WHOSE GREATEST DIAMETERS DOES NOT EXCEED 5 cm. B - ONE OR MORE OPACITIES LARGER OR MORE NUMEROUS THAN THOSE IN CATEGORY A WHOSE COMBINED AREA DOES NOT EXCEED ONE THIRD OF THE VISIBLE RIGHT LUNG. C - ONE OR MORE OPACITIES WHOSE COMBINED AREA EXCEEDS ONE THIRD OF THE VISIBLE RIGHT LUNG FIELD	
EGGSHELL CALCIFICATIONS (ES)	SPECIFIC CRITERIA FOR IDENTIFYING EGGSHELL CALCIFICATIONS AS EVIDENCE OF SILICOSIS: (1) THE PRESENCE OF SHELL-LIKE CALCIFICATIONS MEASURING UP TO 2 mm IN THICKNESS IN THE PERIPHERAL ZONE OF AT LEAST TWO LYMPH NODES. (2) THESE CALCIFICATIONS MAY BE SOLID OR BROKEN. (3) IN AT LEAST ONE OF THE LYMPH NODES THE RING-LIKE SHADOW MUST BE COMPLETE. (4) THE CENTRAL PORTION OF THE LYMPH NODE MAY SHOW, IN ADDITION, SPECKLED CALCIFICATION. (5) THE AFFECTED LYMPH NODE MUST BE AT LEAST 1 cm IN ITS GREATEST DIAMETER	

CODE FOR ADDITIONAL SYMBOLS

- ax - SUSPECT COALESCENCE OF SMALL PNEUMOCONIOTIC OPACITIES
- ca - SUSPECT CANCER OF THE LUNG
- cn - CALCIFICATION IN SMALL OPACITIES
- co - ABNORMALITIES OF THE CARDIAC OUTLINE. TO BE REPLACED BY "cp-cor pulmonale" IF THIS CONDITION IS STRONGLY SUSPECTED
- cv - CAVITY
- di - SIGNIFICANT DISPLACEMENT OR DISTORTION OF THE INTRA-THORACIC ORGANS
- em - EMPHYSEMA
- es - EGGSHELL CALCIFICATION OF LYMPH NODES
- hi - APPRECIABLE ENLARGEMENT OF THE HILAR SHADOWS
- pl - ABNORMALITY OF THE PLEURA
- px - PNEUMOTHORAX
- rl - PNEUMOCONIOSIS MODIFIED BY THE RHEUMATOID PROCESS
- tb - OPACITIES SUGGESTIVE OF INACTIVE TUBERCULOSIS, EXCLUDING THE CALCIFIED PRIMARY COMPLEX
- tba - OPACITIES SUGGESTIVE OF ACTIVE TUBERCULOSIS
- nt - NON-TUBERCULOUS INFECTION
- np - PROBABLY NOT PNEUMOCONIOSIS

* THE BACKGROUND OF SMALL OPACITIES SHOULD BE SPECIFIED AS FAR AS POSSIBLE.

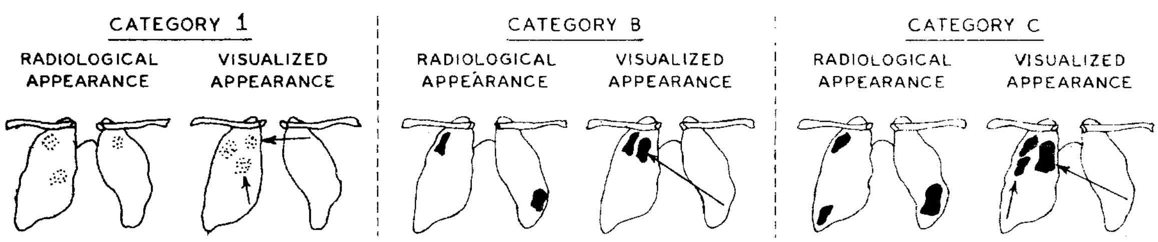

Figure 16.—International radiological classification of chest films modified for U.S.P.H.S. chest studies

TABLE 21—*Detailed classification by pneumoconiosis.*

Category	Working miners		Nonworking miners	
	Number	Percent	Number	Percent
No pneumoconiosis	2,146	84.9	883	74.9
Suspect pneumoconiosis	135	5.3	81	6.9
Simple pneumoconiosis [a]	172	6.8	108	9.2
Complicated pneumoconiosis	76	3.0	106	9.0
No roentgenograms	20		13	
Simple pneumoconiosis:				
1p			5	.4
1q	33	1.3	15	1.3
1r	8	.3	4	.3
2p	24	.9	12	1.0
2q	83	3.3	47	4.0
2r	15	.6	8	.7
3p			10	.8
3q	8	.3	5	.4
3r	1	(*)[b]	2	.2
Total	172	6.8	108	9.2
Complicated pneumoconiosis:				
A1p			1	.1
A1q	6	.2	5	.4
A1r	2	.1	2	.2
A2p	3	.1	6	.5
A2q	22	.9	25	2.1
A2r	4	.2	10	.8
A3p	2	.1	3	.3
A3q	6	.2	1	.1
A3r	1	(*)	3	.3
A only	1	(*)	5	.4
A–Z	3	.1		
B1q	1	(*)		
B2p	1	(*)	2	.2
B2q	11	.4	14	1.2
B2r	4	.2	6	.5
B3p	1	(*)	1	.1
B3q	2	.1	3	.3
B3r	4	.2	3	.3
B only			1	.1
C2p			2	.2
C2q			6	.5
C2r			3	.3
C3p	1	(*)	1	.1
C3q			1	.1
C3r	1	(*)	1	.1
C–Z			1	.1
Total	76	3	106	9

[a] Simple pneumoconiosis includes 41 cases in "ax" classification for each group, i.e., working and nonworking miners.
[b] Asterisk indicates less than 0.1 percent.

TABLE 22—*History of dust on the lung by degree of pneumoconiosis.*

Degree of pneumoconiosis	Working miners		Nonworking miners	
	Number	Percent	Number	Percent
Positive history of dust on the lung:				
No pneumoconiosis	106	53.8	209	53.2
Suspect pneumoconiosis	14	7.1	34	8.7
Simple pneumoconiosis	39	19.8	63	16.0
Complicated pneumoconiosis	38	19.3	87	22.1
Total	197	100.0	393	100.0
No history of dust on the lung:				
No pneumoconiosis	2,031	87.4	661	85.9
Suspect pneumoconiosis	121	5.2	45	5.9
Simple pneumoconiosis	133	5.7	44	5.7
Complicated pneumoconiosis	38	1.7	19	2.5
Total	2,323	100.0	769	100.0
Unknown history or no roentgenograms	29	....	29	....

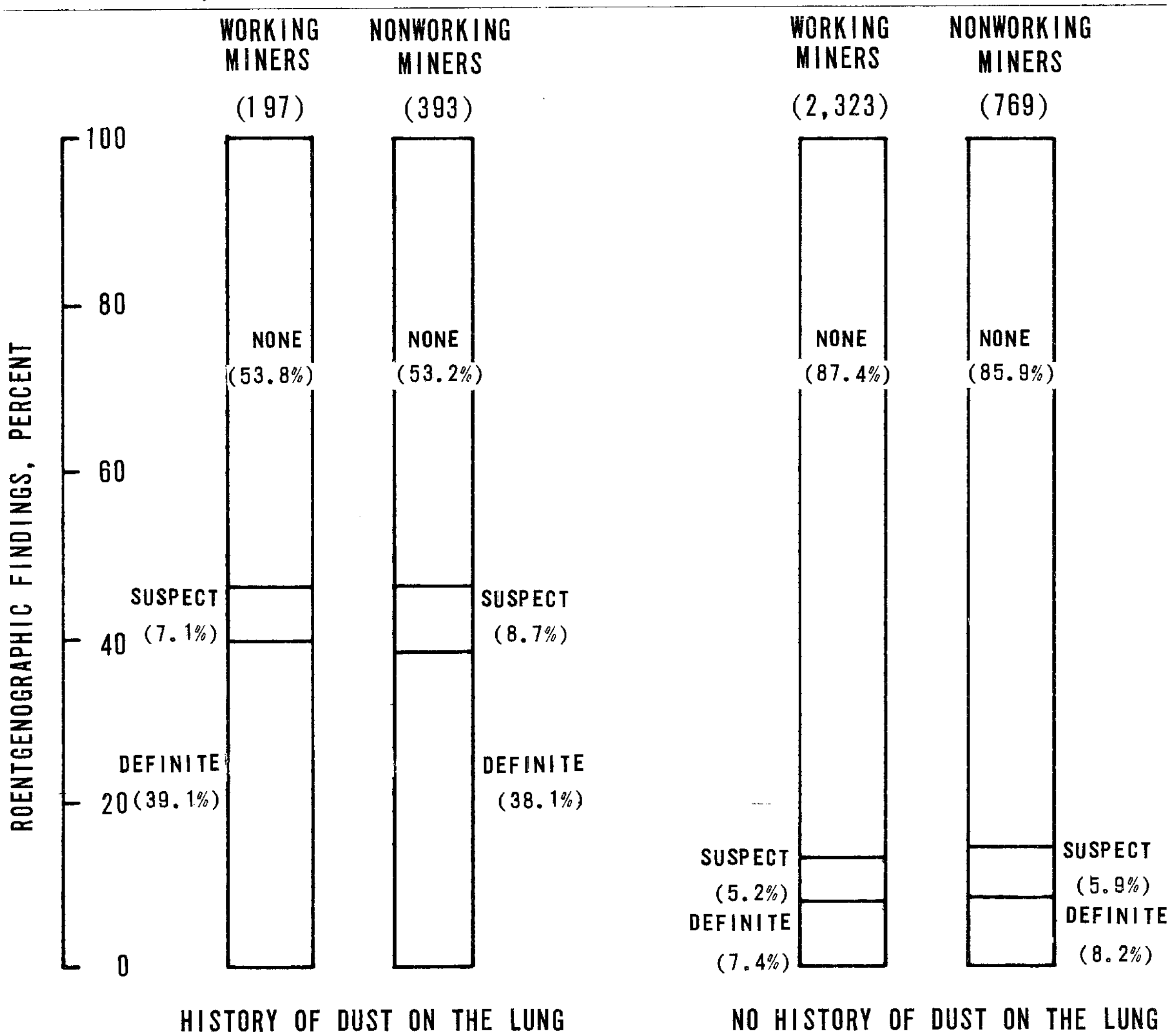

Figure 17.—Comparison of history of dust on the lung with roentgenographic findings

TABLE 23—*Roentgenographic findings by principal occupation.*

Occupation	Degree of pneumoconiosis			Total
	None	Suspect	Definite	
WORKING MINERS				
Underground:				
Face	829	76	153 (14.5)[a]	1,058
Transportation	468	25	52 (9.5)	545
Maintenance	328	14	15 (4.2)	357
Miscellaneous	143	11	18 (10.5)	172
Total	1,768	126	238 (11.2)	2,132
Surface:				
Transportation	43	2	2 (4.3)	47
Maintenance	105	1	1 (0.9)	107
Tipple work	152	4	5 (3.1)	161
Miscellaneous	75	1	2 (2.6)	78
Total	375	8	10 (2.5)	393
Unknown history or no roentgenogram				24
NONWORKING MINERS				
Underground:				
Face	493	48	129 (19.3)	670
Transportation	160	17	64 (26.6)	241
Maintenance	107	6	13 (10.3)	126
Miscellaneous	4	1	2 (*)[b]	7
Total	764	72	208 (19.9)	1,044
Surface:				
Transportation	8	....	1 (*)	9
Maintenance	37	....	2 (5.1)	39
Tipple work	55	7	1 (1.6)	63
Miscellaneous	8	....	1 (*)	9
Total	108	7	5 (4.2)	120
Unknown history or no roentgenogram				27

[a] Percentage.
[b] Asterisk indicates less than 10 miners in job classification.

as underground workers as opposed to only 2.5 percent of those classified as surface workers. Although over 14 percent of the roentgenograms of those whose principal occupation involved face activities showed pneumoconiosis, about 10 percent of the men employed principally in transportation and miscellaneous activities had definite pneumoconiosis. Of the present surface workers, those with transportation jobs had most roentgenographic changes consistent with pneumoconiosis. Similar patterns were seen among the nonworking coal miners although they exhibited a higher overall increase of roentgenographic markings than those presently working.

A further breakdown on workers whose principal occupation was at the face and in transportation indicates that certain underground activities are associated with an increased prevalence of pneumoconiosis (Table 24 and Figure 19). The prevalence of pneumoconiosis in presently employed cutting machine operators is almost 50 percent more than in the average underground face worker (22.3 percent as against 14.5 percent). Loading machine operators also had higher

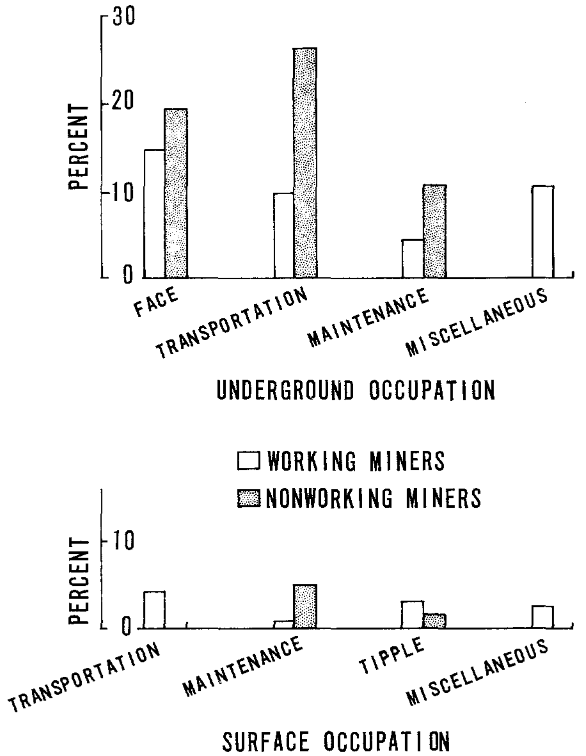

Figure 18.—Roentgenographic findings of definite pneumoconiosis by principle occupation among working and nonworking miners

than average roentgenographic shadows consistent with pneumoconiosis (17.6 percent). Roentgenograms of working motormen and brakemen indicated a prevalence of 13.6 percent definite pneumoconiosis compared to an overall average of 9.5 percent for all underground transportation workers. Roentgenograms of nonworking miners showed similar results although the underground transportation workers had the highest prevalence of pneumoconiosis (26.6 percent). The nonworking cutting machine operators and motormen and brakemen had the highest prevalence of definite pneumoconiosis (33.3 and 31.6 percent, respectively).

Among working miners, the prevalence of roentgenographic evidence of pneumoconiosis is related directly to increasing age and years of underground experience (Table 25 and Figure 20).

In all age groups, there is an incremental increase in the incident percentage with increase of underground experience. Likewise, pneumoconiosis increases as age increases among men with a similar underground experience, which may well be associated with years in coal mining in either surface or underground activities. The prevalence of pneumoconiosis exceeded 17 percent in working miners 45 years of age and older having more than 30 years underground. Definite pneumoconiosis was found in over 20 percent of those nonworking miners over 45 years of age who had more than 20 years mining experience.

For work periods less than 15 years underground, the occurrence of roentgenographic evidence of definite pneumoconiosis appeared to be spotty among all working coal miners (Table 26 and Figure 21) and showed no particular trend. For work periods greater than 15 years underground, there was a linear increase in the prevalence of the disease with years spent underground. The regression curve noted was based on the data available for miners with 15 or more years underground and where there were five or more men in any year-underground group.

A similar experience was noted among those whose principal occupation was noted as face workers (Table 27 and Figure 22). Among workers with a principal occupation of surface activities, only 10 cases of definite pneumoconiosis were reported among the 393 men so classified. One case appeared in a man with less than 15 years experience; the remainder, in those with 15 or more years of coal mining experience.

Roentgenographic Findings and Respiratory Symptoms

Persistent productive cough

Persistent cough with phlegm production is associated with those lesions consistent with pneumoconiosis (Table 28, Figure 23). Of those working miners with no roentgenographic evidence of pneumoconiosis, 8.9 percent reported persistent productive cough whereas 13.4 percent of those with simple pneumoconiotic shadows and 11.9 percent with complicated pneumoconiosis reported the same symptoms. In general, nonworking miners reported more persistent productive cough, but only those with complicated pneumoconiosis had an increased prevalence of such cough.

Dyspnea

Dyspnea was reported more often in working miners with roentgenographic evidence of pneu-

TABLE 24—*Roentgenographic findings by specific underground face and transportation activities.*

Occupation	Degree of pneumoconiosis			Total
	None	Suspect	Definite	
WORKING MINERS				
Face activities:				
Cutting machine operators	155	26	52 (22.3) [a]	233
Hand loaders	330	25	44 (11.0)	399
Loading machine operators	137	13	32 (17.6)	182
Other face operations	207	12	25 (10.2)	244
Total	829	76	153 (14.5)	1,058
Underground transportation:				
Motormen and brakemen	268	19	45 (13.6)	332
Drivers and mule skinners	12	....	....	12
Shuttle car operators	150	4	5 (3.1)	159
Other operations	38	2	2 (4.8)	42
Total	468	25	52 (9.5)	545
NONWORKING MINERS				
Face activities:				
Cutting machine operators	87	9	48 (33.3)	144
Hand loaders	297	29	57 (14.9)	383
Loading machine operators	29	2	9 (22.5)	40
Other face operations	80	8	15 (14.6)	103
Total	493	48	129 (19.3)	670
Underground transportation:				
Motormen and brakemen	116	14	60 (31.6)	190
Drivers and mule skinners	16	1	1 (5.6)	18
Shuttle car operators	17	1	....	18
Other operations	11	1	3 (20.0)	15
Total	160	17	64 (26.6)	241

[a] Percentage.

moconiosis than in those classified negative for this condition (Table 29 and Figure 23). About 3.0 percent of the working miners whose roentgenograms showed no signs of pneumoconiosis reported marked or severe shortness of breath, whereas 7.0 percent of those with simple and 5.3 percent with complicated pneumoconiosis reported this condition. Among the nonworking miners, those men with complicated pneumoconiosis reported a higher incidence of dyspnea (52.4 percent) than did those whose roentgenograms showed no evidence at all (34.3 percent).

Roentgenographic Findings and Cigarette Smoking

The degree of roentgenographic evidence of pneumoconiosis was not related to cigarette smoking. There appeared to be slightly fewer lung changes in present smokers (8.1 percent with definite pneumoconiosis) than in past smokers (13.1 percent) or in those miners who never smoked (11.6 percent) although the latter two groups were slightly older than the present smokers (Table 30). The degree of pneumoconiosis was not related to the number of cigarettes smoked daily (Table 31).

Chest Diseases other than Pneumoconiosis

Each chest roentgenogram was also read for abnormalities other than pneumoconiosis. When a condition other than pneumoconiosis was seen that the radiologist believed warranted prompt

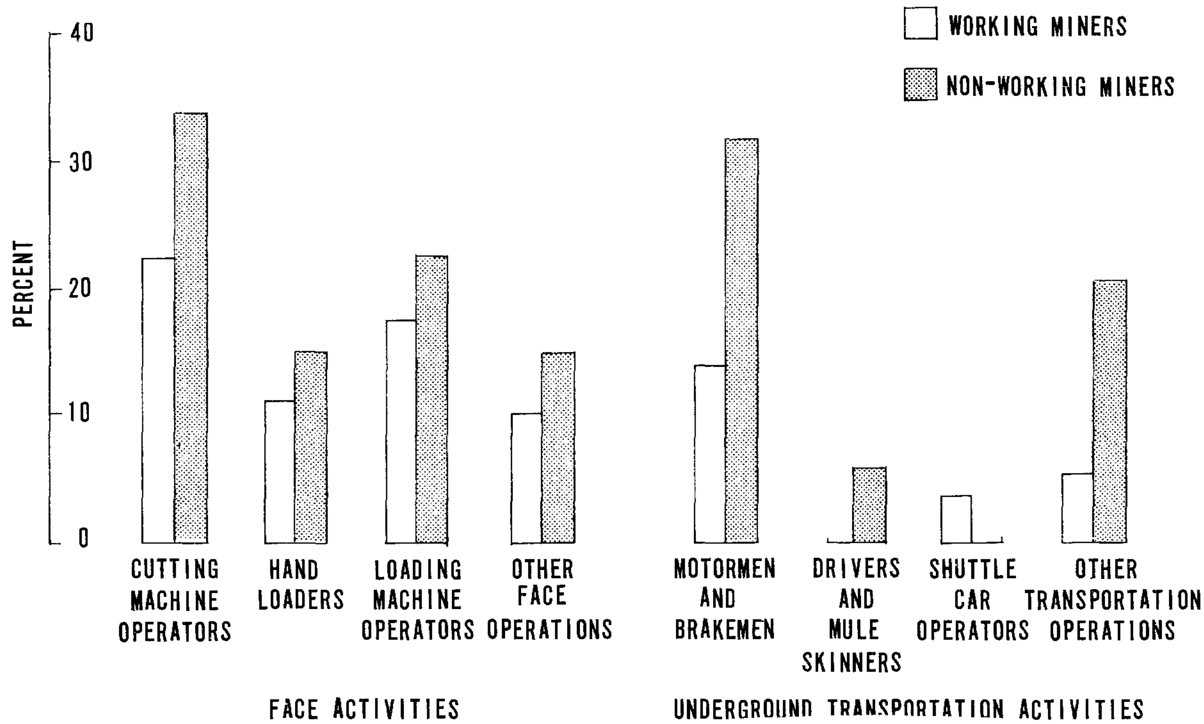

Figure 19.—Roentgenographic findings of definite pneumoconiosis by specific underground face and transportation occupations among working and nonworking miners

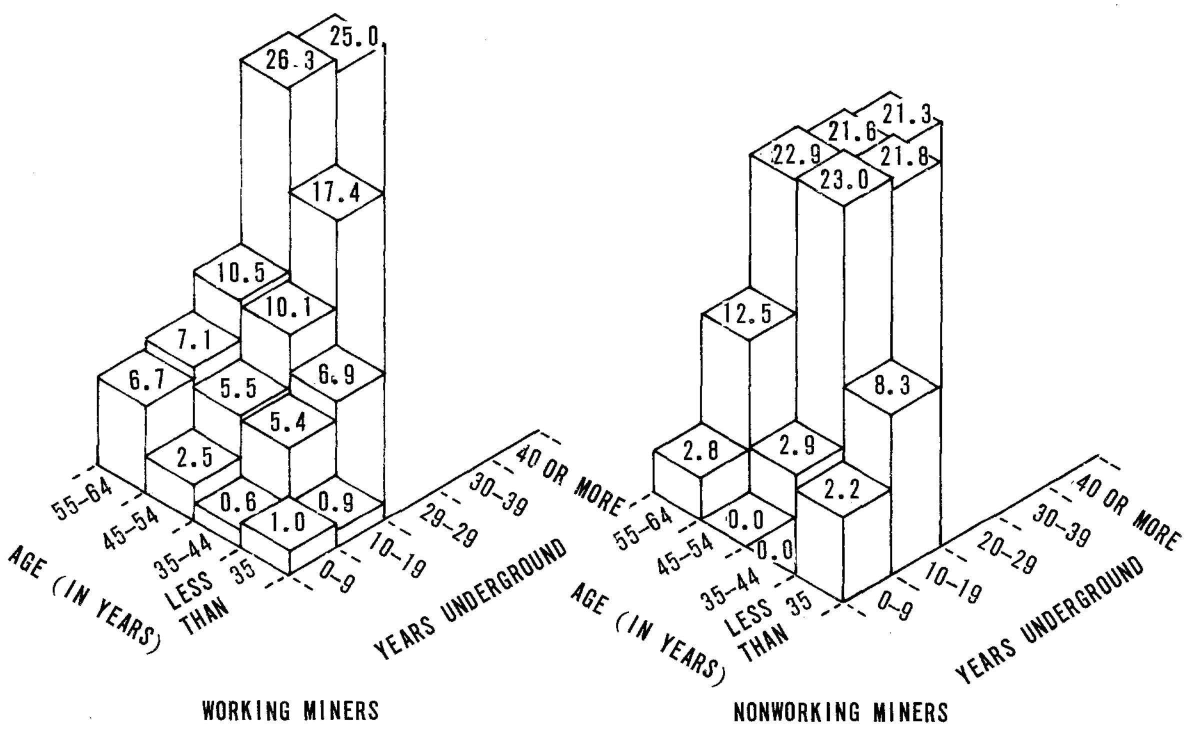

Figure 20.—Roentgenographic findings of definite pneumoconiosis by age and years underground among working and nonworking miners

TABLE 25—*Roentgenographic findings by age and underground experience among working and nonworking miners.*

Age group and degree of pneumoconiosis	Years underground: 0 through 9		10 through 19		20 through 29		30 through 39		40 or more		Total	
	Working	Nonworking	Working	Nonworking	Working	Nonworking	Working	Nonworking	Working	Nonworking	Working	Nonworking
Less than 35 years:												
None	198	2	103	1	1	0	0	0	0	0	302	3
Suspect	0	0	3	0	0	0	0	0	0	0	3	0
Definite	2 (1.0)[a]	* 1[b]	1 (0.9)	*0	*0	*0	*0	*0	*0	*0	3	0
Total	200	2	107	1	1	0	0	0	0	0	308	3
35 through 44 years:												
None	153	19	317	43	205	9	1	0	0	0	676	71
Suspect	2	0	15	1	12	2	1	0	0	0	30	3
Definite	1 (0.6)	*0	19 (5.4)	1 (2.2)	16 (6.9)	1 (8.3)	*0	*0	*0	*0	36	2
Total	156	19	351	45	233	12	2	0	0	0	742	76
45 through 54 years:												
None	112	12	115	33	354	64	228	37	2	1	811	147
Suspect	3	1	4	0	27	3	19	6	0	0	53	10
Definite	3 (2.5)	*0	7 (5.5)	1 (2.9)	43 (10.1)	20 (23.0)	52 (17.4)	12 (21.8)	*0	*0	105	33
Total	118	13	126	34	424	87	299	55	2	1	969	190
55 through 64 years:												
None	54	62	13	35	62	101	138	276	81	150	348	624
Suspect	2	6	0	0	6	10	19	28	21	20	48	64
Definite	4 (6.7)	2 (2.8)	1 (7.1)	5 (12.5)	8 (10.5)	33 (22.9)	56 (26.3)	85 (21.8)	34 (25.0)	46 (21.3)	103	171
Total	60	70	14	40	76	144	213	389	136	216	499	859
65 or more years:												
None	2	1	1	2	1	8	0	8	2	8	6	27
Suspect	0	1	0	0	0	0	0	0	1	1	1	2
Definite	*0	*0	*0	*0	*0	*1	*0	4 (33.3)	*0	2 (18.2)	0	7
Total	2	2	1	2	1	9	0	12	3	11	7	36
Unknown history or no roentgenogram											24	27

[a] Percentage.
[b] Asterisk indicates less than 10 persons in grouping.

TABLE 26—*Roentgenographic findings by years of underground experience among working miners*

Years underground	Degree of pneumoconiosis: None or suspect	Degree of pneumoconiosis: Definite	Total	Years underground	Degree of pneumoconiosis: None or suspect	Degree of pneumoconiosis: Definite	Total
0	242	2 (0.8)[a]	244	28	71	10 (12.3)	81
1	31	1 (3.1)	32	29	65	7 (9.7)	72
2	32	2 (5.9)	34	30	57	11 (16.1)	68
3	18	0 (0.0)	18	31	54	8 (12.9)	62
4	32	0 (0.0)	32	32	41	5 (10.9)	46
5	22	0 (0.0)	22	33	33	15 (31.2)	48
6	43	1 (2.3)	44	34	44	10 (18.5)	54
7	34	1 (2.9)	35	35	52	11 (17.5)	63
8	37	2 (5.1)	39	36	34	9 (20.9)	43
9	35	1 (2.8)	36	37	34	14 (29.2)	48
10	38	0 (0.0)	38	38	39	13 (25.0)	52
11	34	0 (0.0)	34	39	18	12 (40.0)	30
12	43	0 (0.0)	43	40	19	5 (20.8)	24
13	54	0 (0.0)	54	41	20	6 (23.0)	26
14	61	3 (4.7)	64	42	14	5 (26.4)	19
15	60	2 (3.2)	62	43	13	5 (27.8)	18
16	61	6 (9.0)	67	44	13	6 (31.6)	19
17	87	6 (6.5)	93	45	7	1 (12.5)	8
18	77	7 (8.3)	84	46	6	3 (33.3)	9
19	56	4 (6.7)	60	47	5	3 (37.5)	8
20	80	2 (2.4)	82	48	6	0 (0.0)	6
21	75	13 (14.8)	88	49	1	0 (*)[b]	1
22	71	4 (5.3)	75	50	0	0 (*)	3
23	80	4 (4.8)	84	51–58	3	0 (*)	0
24	49	4 (7.6)	53				
25	54	7 (11.5)	61	Total	2,278	247	2,525
26	62	9 (12.7)	71	Unknown history or no			
27	61	7 (10.3)	68	roentgenogram			24

[a] Percentage.
[b] Asterisk indicates less than 5 persons in grouping.

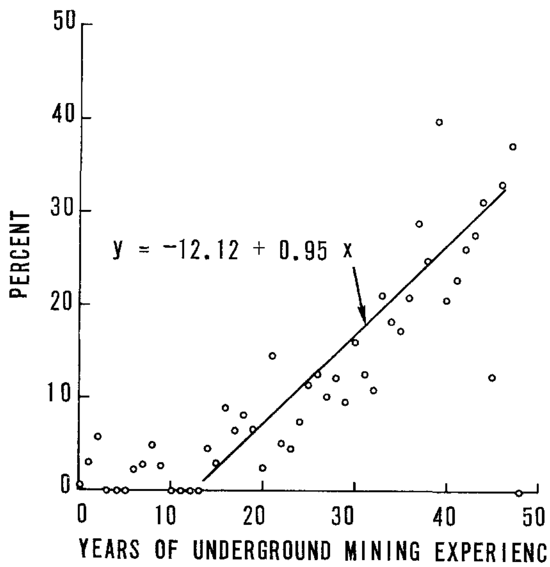

Figure 21.—Definite pneumoconiosis by years of underground experience, working miners

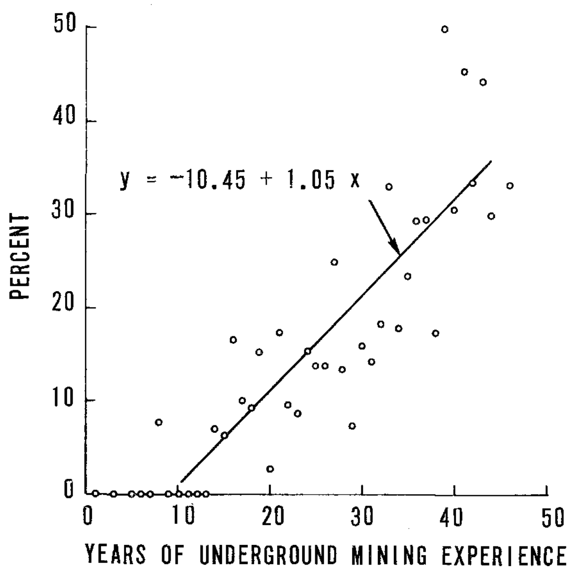

Figure 22.—Definite pneumoconiosis by years of underground experience, working face workers

TABLE 27—*Roentgenographic findings by years of underground experience among faceworkers*

Years underground	Degree of pneumoconiosis: None or suspect	Definite		Total	Years underground	Degree of pneumoconiosis: None or suspect	Definite		Total
0	3	0	(*)[a]	3	27	21	7	(25.0)	28
1	10	0	(0.0)[b]	10	28	32	5	(13.5)	37
2	1	0	(*)	1	29	38	3	(7.3)	41
3	8	0	(0.0)	8	30	26	5	(16.1)	31
4	4	0	(*)	4	31	24	4	(14.3)	28
5	5	0	(0.0)	5	32	22	5	(18.5)	27
6	17	0	(0.0)	17	33	20	10	(33.3)	30
7	11	0	(0.0)	11	34	23	5	(17.9)	28
8	12	1	(7.7)	13	35	26	8	(23.5)	34
9	12	0	(0.0)	12	36	12	5	(29.4)	17
10	13	0	(0.0)	13	37	19	8	(29.6)	27
11	11	0	(0.0)	11	38	19	4	(17.4)	23
12	17	0	(0.0)	17	39	7	7	(50.0)	14
13	24	0	(0.0)	24	40	9	4	(30.8)	13
14	26	2	(7.1)	28	41	6	5	(45.5)	11
15	29	2	(6.5)	31	42	4	2	(33.3)	6
16	25	5	(16.7)	30	43	5	4	(44.4)	9
17	44	5	(10.2)	49	44	7	3	(30.0)	10
18	49	5	(9.3)	54	45	4	0	(*)	4
19	22	2	(15.4)	26	46	4	2	(33.3)	6
20	35	1	(2.8)	36	47	0	2	(*)	2
21	28	6	(17.6)	34	48	2	0	(*)	2
22	37	4	(9.8)	41	49	0	0	(*)	0
23	42	4	(8.7)	46	50	0	0	(*)	0
24	22	4	(15.4)	26	51	1	0	(*)	1
25	31	5	(13.9)	36					
26	37	6	(14.0)	43	Total	906	152		1,058

[a] Asterisk indicates less than 5 persons in grouping.
[b] Percentage.

TABLE 28—*History of cough related to roentgenographic findings of pneumoconiosis.*

Degree of cough	Degree of pneumoconiosis: None		Suspect		Simple		Complicated	
	Number	Percent	Number	Percent	Number	Percent	Number	Percent
Working miners:								
No cough or sputum	1,530	71.6	98	72.6	113	66.1	53	69.7
Less than persistent productive cough	416	19.5	26	19.3	35	20.5	14	18.4
Persistent productive cough	190	8.9	11	8.1	23	13.4	9	11.9
Total	2,136	100.0	135	100.0	171	100.0	76	100.0
Unknown history or no roentgenogram	31							
Nonworking miners:								
No cough or sputum	428	49.2	37	46.8	49	46.2	41	38.7
Less than persistent productive cough	242	27.8	24	30.4	33	31.1	32	30.2
Persistent productive cough	200	23.0	18	22.8	24	22.7	33	31.1
Total	870	100.0	79	100.0	106	100.0	106	100.0
Unknown history or no roentgenogram	30							

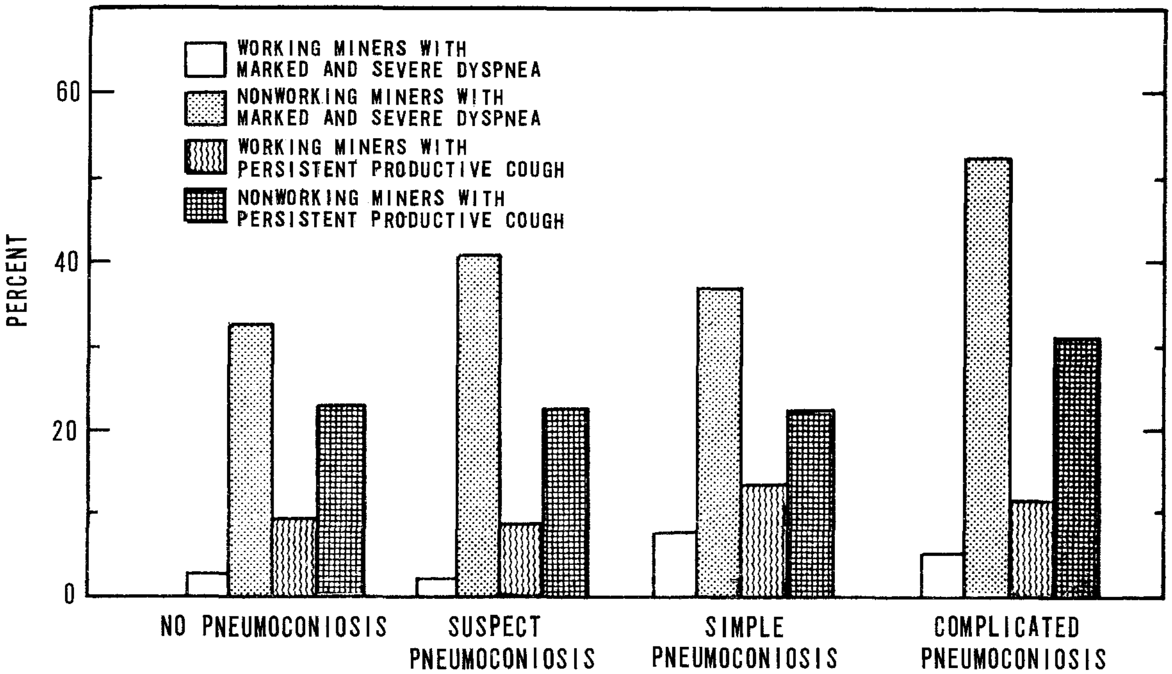

Figure 23.—Cough and dyspnea by degree of pneumoconiosis among working and nonworking miners

TABLE 29—*History of dyspnea related to roentgenographic findings of pneumoconiosis.*

Degree of dyspnea	Degree of pneumoconiosis							
	None		Suspect		Simple		Complicated	
	Number	Percent	Number	Percent	Number	Percent	Number	Percent
Working miners:								
None or slight	1,893	88.6	113	83.7	132	76.7	55	72.3
Moderate	173	8.1	19	14.1	28	16.3	17	22.4
Marked and severe	70	3.3	3	2.2	12	7.0	4	5.3
Total	2,136	100.0	135	100.0	172	100.0	76	100.0
Unknown history or no roentgenogram	30							
Nonworking miners:								
None or slight	401	47.9	33	42.3	46	44.7	24	23.3
Moderate	149	17.8	13	16.7	19	18.4	25	24.3
Marked and severe	287	34.3	32	41.0	38	36.9	54	52.4
Total	837	100.0	78	100.0	103	100.0	103	100.0
Unknown history or no roentgenogram	70 [a]							

[a] Of nonworking miners, 44 disabled due to noncardiopulmonary causes.

treatment or further diagnostic study, the private physician named by the miner at the time of his examination was notified. Such notices were mailed to 162 physicians during the prevalence study (Table 32). About 3.0 percent of the working miners' physicians were so notified, with two-thirds of these notices reporting suspected tuberculosis or neoplasm. About twice as many nonworking miners (6.4 percent) were referred to their physicians for similar reasons.

TABLE 30—*Roentgenographic findings related to smoking history among working miners.*

Degree of pneumoconiosis	Present smokers		Past smokers		Nonsmokers		Total
None	1,334	(87.1) [a]	379	(77.9)	423	(85.2)	2,136
Suspect	74	(4.8)	44	(9.0)	16	(3.2)	134
Simple	89	(5.8)	45	(9.2)	38	(7.6)	172
Complicated	35	(2.3)	19	(3.9)	20	(4.0)	74
Total	1,532	(100.0)	487	(100.0)	497	(100.0)	2,516
Mean age	45.1		48.1		46.9		....
Unknown smoking history or no roentgenogram							33

[a] Percentage.

TABLE 31—*Roentgenographic findings related to number of cigarettes smoked among working miners.*

Degree of pneumoconiosis	Number of cigarettes smoked daily				Total
	Less than 20		20 or more		
None	1,055	(84.7) [a]	1,079	(85.2)	2,134
Suspect	61	(4.9)	71	(5.6)	132
Simple	86	(6.9)	85	(6.7)	171
Complicated	43	(3.5)	31	(2.4)	74
Total	1,245	(100.0)	1,266	(100.0)	2,511
Mean age	46.1		46.0		....
Unknown smoking history or no roentgenogram					38

[a] Percentage.

TABLE 32—*Referral letters to physicians of miners for chest conditions other than pneumoconiosis.*

Medical condition reported	Working miners		Nonworking miners	
	Number	Percent	Number	Percent
Tuberculosis, activity undetermined	28	1.1	34	2.9
Tumor or suspected cancer	19	.7	18	1.5
Abnormalities of cardiac outline	6	.2	8	.7
Basal pulmonary disease	7	.3	6	.5
Hilar enlargement	5	.2	2	.1
Other conditions	9	.4	7	.6
Total referrals	74	2.9	75	6.4
Total examined	2,545	....	1,178	....

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SECTION IV

Prevalence of Respiratory Symptoms in Two Appalachian Communities

Prevalence of Respiratoy Symptoms in Two Appalachian Communities

PHILIP E. ENTERLINE, Ph.D.

A variety of factors are no doubt responsible for such respiratory symptoms as chronic cough, sputum production, and dyspnea, which are associated with coal workers' pneumoconiosis. Many of these factors are part of the general living environment. Individual susceptibility, cigarette smoking, general air pollution, and respiratory infections probably play important roles.

The exact role of coal mine dust in causing respiratory symptoms is not clear. Studies of mortality rates among American coal miners show little excess in diseases of the respiratory system other than pneumoconiosis.[1] Brinkman and Coates [2] report that the amount of exposure to silica dust seems to have little influence on the prevalence of bronchitis. British coal miners show an excess in deaths from bronchitis and pneumonia; there is some evidence, however, that this is due mainly to factors outside the mining environment.[3] On the other hand, some morbidity studies suggest that dust exposures in connection with coal mining are important in the development of respiratory symptoms. Bohme and Lent [4] found bronchitis to be twice as prevalent among underground mine workers as among mine office-workers. Random sampling of populations in two areas of Wales revealed a higher prevalence of respiratory symptoms and a reduced ventilatory capacity in coal miners than in men who had never mined,[5, 6] however, a subsequent study of a third area found that the symptomatology of elderly miners and nonworking miners was not strikingly different from men who had never worked in "dusty" occupations.[7]

In view of the varied evidence it is not surprising that workmen's compensation policies also vary with regard to evaluation of impairment associated with nonspecific respiratory symptoms. In the United States, a miner without radiographic evidence of pneumoconiosis rarely qualifies for workmen's compensation for respiratory disease. In South Africa, however, over half of the gold miners receiving workmen's compensation for respiratory disease do so because of chronic bronchitis and emphysema.[8]

STUDY DESIGN

If a group of coal miners could be matched with a group of nonminers for relevant variables such as social and economic histories, etc., and then if the groups were compared on the basis of selected health characteristics, it would be possible to determine to some extent the deleterious effects associated strictly with the mining occupation. Information on health histories of all wives would also be useful. If the nonoccupational environment differed between miners and other manual workers, and if this difference had an important effect on respiratory symptoms, it would be expected that wives of the two groups of workers would also differ since they largely shared this nonoccupational environment with their husbands. If, on the other hand, the nonoccupational environment was not important in the comparisons sought, then it might be anticipated that the prevalence of respiratory symptoms among wives of the two groups would be quite similar. The approach of this study was based on these considerations.

The situation best suited to this study would be one where men, on entering the labor force, are randomly assigned either to coal mining or to some nondusty occupation and where all subsequent social, economic, and other disease-related factors are similar. Obviously such a study is not possible. It was believed, however, that such a model might be approached in some communities where sufficient competition for workers existed between dusty and nondusty industries. Thus, communities were sought that met the following criteria: (1) the male labor force should be divided as equally as possible between underground coal mining and nondusty industry (or industries) requiring comparable manual skills and providing about the same economic returns to the workers; (2) the industries should be fairly stable and should have existed for a long enough time so that men currently at work would show long histories of employment in their present jobs; (3) the communities should not be so large that a complete census would be cost prohibitive, yet large enough that findings could be considered meaningful; (4) the communities should be sufficiently isolated geographically to permit an easy description of the places of employment and of the medical facilities and services available to the area residents; and (5) the communities should be political entities so that demographic data would be available. The decision to conduct studies in two areas rather than only one, or several, was governed by the desire for some replication of data as well as by restrictions on time and money available for these studies.

An intensive search for possible sites in the bituminous coal fields in West Virginia and Pennsylvania resulted in the selection of two communities that approached these criteria: Mullens and Richwood, W. Va. Mullens, a community of about 5,000 persons, is located in the southern part of the State.* Until 1912, the economy of this area was based largely on picking and selling ginseng root and on lumbering. In 1912, the railroad came into Mullens and coal mining became important. For most of the period since then, Mullens has been the division headquarters of a major railroad and many men not in mining have been employed in railroad marshalling yards or shops.

Richwood, also a community of about 5,000, is located in east central West Virginia about 100 miles east of Charleston. The economy of the area was based largely on lumbering, sawmilling, and wood manufacturing until about 1940 when extensive coal mining began.

Although the mining operations in Mullens and Richwood are similar, the type of coal mined is somewhat different. In the Mullens area, the mined coal is less volatile and of higher rank than that found in the Richwood area. The level of air pollution in the two towns also probably differs. Mullens, located in a sharp valley with coal cleaning plants in the area, is thought to have a higher level of air pollution than Richwood.

In each of the two communities an extensive household interview was conducted, under contract with the Opinion Research Corporation of Princeton, N.J. (see Appendix 2 for questionnaire). In every household where a male 21 years or older was in residence, all persons over 21 were interviewed. The interview was designed to determine basic demographic data, occupational history, smoking history, history of selected diseases or conditions, accidental injuries, selected impairments, hospitalization and medical care, frequency of occurrence of selected symptoms (including dyspnea and productive cough), and disability resulting from reported conditions.

On the basis of the data accumulated during these household interviews, matched groups of miners and nonminers, aged 21 to 64 years, were selected from each community and invited, along with their wives, to participate in a medical examination. In Mullens, men were matched on the basis of age, length of residence in West Virginia, and length of time in usual occupation (coal mining or other industry). One year later in Richwood, they were matched on the basis of age, educational level, and residence history. The significance of educational level to respiratory disease was not realized until after the Mullens group was chosen (Tables 33 and 34).

RESULTS OF HOUSEHOLD INTERVIEWS

Tables 35, 36, and 37 summarize some of the results of the household interviews in the two communities. In both communities, response to the interviews was excellent. Only about 1 percent of individuals in households in Mullens and only 2 percent in Richwood could not be interviewed. Few Negroes live in Mullens, and there were only two families in Richwood. Annual family incomes were considerably higher in Mullens than in Richwood, although home ownership was slightly higher in Richwood (Table 35).

The number of persons 21 and over was fairly equal for the two communities, although there was some difference in the age distribution, with relatively more persons at ages 65 and over in Richwood than in Mullens. Educational levels were somewhat lower in Richwood. Cigarette smoking was about the same in the two areas. There were

* The community actually studied included the town of Mullens and adjacent small communities of Tralee, Itmann, Caloric, and Otsego. In the material presented here, this area will be referred to simply as Mullens.

TABLE 33—*Selected results of medical examination by age and educational level among coal miners at Mullens and Richwood*

Medical examination item	Under 45				45 and over			
	8th grade or less		More than 8th grade		8th grade or less		More than 8th grade	
Number examined	80	(100.0)[a]	116	(100.0)	111	(100.0)	51	(100.0)
Cigarette smoking (pack years)	17.7		15.0		31.6		29.1	
Cough and phlegm:								
Any cough	19	(23.8)	14	(12.1)	41	(37.3)	5	(9.8)
>3 mos >3 yrs[b]	12	(15.0)	7	(6.0)	27	(24.5)	3	
Any Phlegm	16	(20.0)	9	(7.8)	33	(28.9)	7	(13.1)
>3 mos >3 yr	10	(12.5)	6	(5.2)	24	(21.6)	2	
Wheezing:								
Any wheezing	38	(47.5)	54	(46.6)	73	(65.8)	27	(52.9)
With colds only	24	(30.0)	39	(33.6)	30	(27.0)	17	(33.3)
Other times, too	14	(17.5)	15	(12.9)	43	(38.7)	10	(19.6)
Dyspnea:								
Any dyspnea	51	(67.1)	60	(53.1)	98	(90.7)	40	(80.0)
Grade 3 (moderate) or worse	9	(11.2)	9	(7.7)	40	(37.0)	7	(14.0)
General health (self-evaluation):								
Very good, good	41	(51.3)	73	(63.5)	50	(45.9)	26	(51.0)
Fair	33	(41.3)	39	(33.9)	41	(47.6)	21	(41.2)
Poor, bad	6	(7.5)	3		18	(16.5)	4	
History of pneumonia:								
Any history	26	(32.5)	36	(31.0)	55	(49.5)	20	(39.2)
Before age 18 only	10	(12.5)	16	(13.8)	14	(12.6)	6	(11.8)
18 or later	16	(20.0)	20	(17.2)	41	(36.9)	14	(27.5)
Single episode	11	(13.8)	18	(15.5)	24	(21.6)	13	(25.5)
Multiple episodes	12	(15.0)	15	(12.9)	17	(15.3)	6	(11.8)
History of pleurisy:								
Any history	11	(13.8)	11	(9.5)	24	(21.6)	13	(25.5)
Before age 18 only	2		2		1		1	
18 or later	9	(11.3)	9	(7.8)	23	(20.7)	12	(23.5)
Single episode	8	(10.0)	6	(5.2)	18	(16.2)	7	(13.7)
Multiple episodes	3		2		2		2	
Roentgenographic findings:								
Pneumoconiosis	4		9	(7.8)	27	(24.5)	12	(24.0)
Suspect	2		3		5	(4.5)	6	(12.0)
Simple	2		6	(5.2)	13	(11.8)	3	
Complicated	0		0		9	(8.2)	3	

[a] Number in parentheses is percentage of the total number of examinees from whom information was available. Percentages were not calculated for less than 5 cases.
[b] Present most days for more than 3 months a year and for more than 3 years.

more respiratory symptoms reported in Mullens than in Richwood with a marked difference in persistent phlegm. Dyspnea was also somewhat more frequent in Mullens; hospitalization during the previous year did not differ much between the two communities, however. More of those interviewed in Mullens had seen a doctor during the past year than had in Richwood (Table 36).

In both areas, slightly more than half of the adult men with a work history had at some time worked in mining and about a third were currently engaged in mining. In both areas, a very high proportion of the men were born in West Virginia and were of English, Irish, Scotch, or Welsh descent (Table 37).

Certain information obtained from the miners in the household interview is compared with that from the nonminers invited for medical examinations (Table 38). The fact that the two working groups in Mullens were not matched on education level but were in Richwood explains the difference in educational levels between the miners and nonminers in Mullens that appears in Table 38. The difference in the method of matching may explain some of the other differences shown in Table 38: for example, Richwood miners invited for ex-

TABLE 34—*Selected results of medical examination by age and educational level among other workers at Mullens and Richwood*

Medical examination item	Under 45				45 and over			
	8th grade or less		More than 8th grade		8th grade or less		More than 8th grade	
Number examined	36	(100.0)[a]	130	(100.0)	105	(100.0)	71	(100.0)
Cigarette smoking (pack years)	21.2		14.4		36.4		34.7	
Cough and phlegm:								
Any cough	6	(16.7)	18	(13.8)	25	(23.8)	13	(18.3)
>3 mo >3 yr[b]	3		11	(8.5)	15	(14.3)	5	(7.0)
Any phlegm	6	(16.7)	15	(11.5)	23	(21.9)	13	(18.3)
>3 mo >3 yr	3		11	(8.5)	16	(15.2)	10	(14.1)
Wheezing:								
Any wheezing	21	(58.3)	49	(37.7)	56	(53.3)	23	(32.4)
With colds only	15	(41.7)	32	(24.6)	29	(27.6)	15	(21.1)
Other times too	6	(16.7)	17	(13.1)	27	(25.7)	8	(11.3)
Dyspnea:								
Any dyspnea	20	(55.6)	69	(53.1)	71	(69.6)	45	(65.2)
Grade 3 (moderate) or worse	3		4		21	(20.6)	12	(17.4)
General health (self-evaluation):								
Very good, good	16	(45.7)	88	(70.4)	55	(53.9)	44	(63.8)
Fair	17	(48.6)	34	(27.2)	34	(33.3)	22	(31.9)
Poor, bad	2		3		13	(12.7)	3	
History of pneumonia:								
Any history	13	(36.1)	23	(17.7)	36	(34.3)	23	(31.5)
Before age 18 only	6	(16.7)	12	(9.2)	10	(9.5)	12	(16.9)
18 or later	7	(9.4)	11	(8.5)	26	(24.8)	11	(15.5)
Single episode	6	(16.7)	11	(8.5)	21	(20.0)	10	(14.1)
Multiple episodes	5	(13.9)	10	(7.7)	10	(9.5)	10	(14.1)
History of pleurisy:								
Any history	2		4		9	(8.6)	12	(16.9)
Before age 18 only	0		0		1		1	
18 or later	2		4		8	(7.6)	11	(15.5)
Single episode	2		4		7	(6.7)	8	(11.3)
Multiple episodes	0		0		1		1	
Roentgenographic findings:								
Pneumoconiosis	1		0		5	(4.9)	0	
Suspect	1		0		2		0	
Simple	0		0		3		0	
Complicated	0		0		0		0	

[a] Number in parentheses is percentage of the total number of examinees from whom information was available. Percentages were not calculated for less than 5 cases.
[b] Present most days for more than 3 months a year and for more than 3 years.

amination had higher family incomes than the nonminers in Richwood, but in Mullens, incomes were about the same or slightly lower for the nonminers.

Attitudes regarding doctor visits between the two groups did not differ greatly, or consistently, in either area. Coal miners, however, in both Mullens and Richwood tended to see doctors more frequently than did nonminers. This may reflect the fact that medical care is readily available to miners through the United Mine Workers Welfare and Retirement Fund.

RESULTS OF MEDICAL EXAMINATIONS IN MULLENS

In Mullens, the household survey interview was conducted in September and October 1963 and the medical examinations were made in January and February 1964. The 705 miners, nonminers, and wives between the ages of 21 and 64 represented an 85.4 percent response of 825 originally invited to participate. Eighty-eight refused examination, and the remaining had moved, died, or were physically unable to attend the examination. A comparison of the prevalence of respiratory symptoms and

TABLE 35—*Selected results of interviews from households.*

Interview item	Mullens	Richwood
Families and unrelated persons	1,307	1,280
Number not interviewed	16	30
Number for which interviews were conducted	1,291	1,250
Race:		
White	1,201	1,248
Negro	90	2
Family income in past 12 months:		
Under $2,000	203	337
$2,000 to $4,000	222	292
$4,000 to $7,000	507	329
$7,000 or more	301	174
Not ascertained	58	118
Home ownership (primary families):		
Own	753	786
Rent	495	352
Not ascertained or other	22	47

TABLE 36—*Selected results of interviews from individual persons.*

Interview item	Mullens	Richwood
Number of persons 21 years of age or over	2,460	2,345
Sex:		
Male	1,194	1,071
Female	1,266	1,274
Age (last birthday):		
21 through 34	543	564
35 through 44	661	510
45 through 54	616	480
55 through 64	369	396
65 through 74	197	245
75 and over	72	150
Unknown	2	0
Education (highest grade in school):		
8th grade	357	400
12th grade	687	595
Some college	404	312
Cigarette smoking:		
Ever smoked	1,493	1,388
Now smoke	1,162	1,062
Cough first thing	282	262
On most days, 3 months a year or more	150	131
Phlegm first thing in the morning	221	198
On most days, 3 months a year or more	142	114
Dyspnea when:		
Walk fast on level	742	713
Walk with other people	203	196
Walk at own pace	125	118
Washing or dressing	88	72
Patient in a hospital during past year	468	470
Seen doctor:		
In past month	631	594
In past year	1,837	1,662

TABLE 37—*Selected results of interviews from men.*

Interview item	Mullens	Richwood
Men 21 years of age and over	1,194	1,071
Employment history:		
Ever worked	1,188	1,061
Worked in coal mining at some time	651	600
Now in coal mining	375	301
Never worked in coal mining	537	461
Place of birth:		
West Virginia	800	914
Other United States	379	131
Not in United States	15	26
Ethnic origin:		
Don't know	365	209
English, Irish, Scotch, or Welsh	620	577
All other	209	285

TABLE 38—*Selected results of household interviews from men subsequently invited for physical examination.*

	Mullens		Richwood	
	Miners	Nonminers	Miners	Nonminers
Number of men invited for physical examination	225	224	225	224
Education (highest grade in school):				
8th grade or less	110	70	114	113
More than 8th grade	113	152	111	111
Not reported	2	2	0	0
Family income in past 12 months:				
Under $2,000	20	16	24	46
$2,000 to $4,000	30	43	45	80
$4,000 to $7,000	110	98	104	62
$7,000 or more	56	55	39	20
Not ascertained	9	12	13	16
Health attitudes (which makes better sense):				
See doctor only when sick	46	47	65	74
Be examined even if feel well	179	175	159	150
No answer	0	2	1	0
When you feel sick do you:				
Talk to doctor soon	74	81	82	61
Wait till seriously ill	142	135	139	158
No answer	9	8	4	5
Seen doctor:				
In past month	51	51	65	34
In past year	170	148	175	135

other data between respondents and those that did not respond, as revealed during the household interviews, shows little difference, however, and it is believed that results have not been biased by the less than 100 percent participation.

Table 39 presents some of the data from the medical examinations. Percentages related to respiratory symptoms and histories of pneumonia and pleurisy for nonminers have been adjusted by the direct method to the age and education level distribution of miners. Percentages for respiratory symptoms of wives of miners have been adjusted by the direct method to the age and cigarette smoking distribution of the wives of the nonminers. Mean ages for the matched groups were almost identical. Miners averaged close to

TABLE 39—*Selected results of medical examinations.*

Medical examination item	Mullens, men		Richwood, men		Mullens, wives		Richwood, wives	
	Miners	Nonminers	Miners	Nonminers	Miners	Nonminers	Miners	Nonminers
Invited for examination	225	224	225	224	191	185	196	158
Actually examined	185	194	175	153	163	163	156	116
Percentage examined	82.2	86.8	77.8	68.0	85.3	88.1	79.6	73.4
Mean age, years	43.9	43.8	42.8	43.8	40.3	41.0	39.0	42.0
Mean height, inches	68.3	69.1	69.1	69.4	63.3	63.5	64.5	64.3
Mean weight, pounds	166.4	178.1	164.8	166.5	141.5	142.8	151.0	142.3
Cigarette smoking, pack year	23.8	25.0	22.4	27.8	9.7	6.1	8.5	9.1
Cough and phlegm:								
Any cough	49 (26.5)[a]	31 (17.4)	30 (18.7)	31 (20.2)	21 (10.0)	16 (10.0)	17 (10.8)	9 (7.7)
>3 mo >3 yr[b]	26 (14.0)	14 (8.9)	23 (14.1)	20 (13.0)	13 (6.4)	7 (4.2)	9 (5.7)	7 (6.0)
Any phlegm production	47 (25.4)	37 (21.1)	18 (11.1)	20 (13.0)	23 (11.7)	11 (7.0)	11 (7.0)	5 (4.3)
>3 mo >3 yr	28 (15.1)	26 (14.7)	14 (8.9)	14 (9.1)	11 (5.3)	2	5 (3.2)	4
Wheezing:								
Any wheezing	103 (55.7)	89 (49.8)	91 (52.5)	67 (43.7)	56 (34.0)	44 (27.0)	47 (30.1)	37 (31.8)
With colds only	61 (33.0)	57 (32.6)	50 (28.2)	38 (24.8)	27 (17.2)	30 (18.4)	31 (19.8)	25 (21.5)
Other times too	42 (22.7)	32 (17.2)	41 (24.5)	29 (18.9)	29 (16.7)	14 (8.6)	16 (10.3)	12 (10.3)
Dypsnea:								
Disabled, not cardiopulmonary	10	4	1	1	2	2	1	0
Not disabled	174	189	155	152	160	157	155	116
Grade 3 (moderate) or worse	42 (24.1)	27 (14.5)	23 (14.8)	13 (8.5)	37 (22.0)	20 (12.7)	25 (16.1)	13 (11.2)
Grade 5 (severe)	8 (5.0)	7 (4.6)	7 (4.6)	7 (4.6)	13 (7.4)	4	6 (3.9)	2
History of pneumonia:								
Any history	70 (38.0)	49 (26.8)	68 (38.8)	48 (31.4)	53 (32.5)	35 (21.4)	54 (34.6)	28 (24.1)
Before age 18 only	28 (15.0)	19 (9.9)	18 (10.9)	21 (13.7)	22 (13.5)	18 (11.0)	17 (10.9)	12 (10.3)
18 or later	42 (23.0)	30 (18.3)	50 (28.6)	27 (17.6)	31 (19.0)	17 (10.4)	27 (23.7)	16 (13.8)
Single episode	33 (18.0)	25 (14.4)	33 (18.8)	23 (15.0)	24 (15.0)	17 (10.4)	28 (17.9)	14 (12.1)
Multiple episodes	9 (5.0)	16 (7.8)	17 (9.7)	4	7 (4.3)	0	9 (5.8)	2
History of pleurisy:								
Any history	36 (19.4)	21 (9.7)	23 (13.1)	8 (5.2)	25 (15.3)	27 (16.5)	13 (8.3)	16 (13.8)
Before age 18	4	2	2	0	6 (4.0)	2	2	6 (5.2)
18 or later	32 (17.2)	19 (8.7)	21 (12.0)	8 (5.2)	19 (12.0)	25 (15.3)	11 (7.1)	10 (8.6)
Single episode	22 (12.0)	14 (7.0)	17 (9.7)	7 (4.6)	16 (10.0)	19 (12.0)	8 (5.1)	9 (7.8)
Multiple episodes	10 (5.4)	5	4	1	3	6 (4.0)	3	1
Roentgenographic findings:								
Definite pneumoconiosis	25 (13.5)	2	11 (6.3)	1	0	2	0	0
Suspect pneumoconiosis	10 (5.4)	2	6 (3.4)	2	0	2	1	0
Simple pneumoconiosis	15 (8.1)	2	9 (5.1)	1	0	2	0	0
Complicated pneumoconiosis	10 (5.4)	0	2	0	0	0	0	0
Forced expiratory volumes:								
FEV_1 (liters/sec)	2.98	3.18	3.29	3.28	2.32	2.33	2.52	2.46
Total FEV (liters/sec)	4.08	4.15	4.32	4.29	2.94	2.93	3.09	3.05
FEV_1 FEV (percent)	72.6	76.3	75.9	76.4	78.6	78.7	81.3	80.8

[a] Number in parentheses is percentage of the total number of examinees from whom information was available. Percentages for respiratory symptoms among male nonminers and wives of coal miners have been adjusted. Percentages were not calculated for less than 5 cases.
[b] Present most days for more than 3 months a year and for more than 3 years.

an inch shorter and weighed less than nonminers, but the wives differed little in these respects. Data from a detailed cigarette smoking history are summarized in terms of "pack years." This is a measure of the total lifetime history of cigarette smoking and represents equivalent years of smoking one package of cigarettes per day. The lifetime consumption of cigarettes by Mullens miners was slightly below that of nonminers. Wives of miners smoked considerably more than the wives of nonminers. In both Richwood and Mullens, cigarette smoking was clearly related to respiratory symptoms.

Miners reported cough (present most days for more than 3 months a year and for more than 3 years) more frequently than nonminers. Miners' wives reported cough about as frequently as the wives of nonminers and persistent cough somewhat more frequently. The frequency of phlegm production among miners was not much different from that of nonminers; however, miners' wives reported phlegm and persistent cough considerably more frequently than wives of nonminers. Both miners and their wives reported wheezing with colds about as frequently as nonminers and their wives, but more frequently in the absence of colds. Miners and their wives reported dyspnea of grade 3 or worse (moderate) and grade 5 (severe) more frequently than nonminers and their wives,* but, as in the case of some of the other respiratory symptoms, wives of miners appear to be slightly worse off than the miners themselves. If occupational factors are involved in any way in reported cough, phlegm, wheezing, and dyspnea, miners' wives seem to be nearly as affected by their husbands' occupation as the husbands themselves.

All participants were questioned at the time of the medical examination as to history of pneumonia and pleurisy. Miners reported both of these conditions considerably more frequently than nonminers, and their wives reported more pneumonia, but slightly less pleurisy, than wives of nonminers. Pneumonia was somewhat more prevalent before the age of 18 for both miners and their wives than for nonminers and their wives.

* The grading of dyspnea is in accordance with recommendations of the British Medical Research Council—see Appendix 1.

Chest films leave little doubt that roentgenographic evidence of pneumoconiosis is a problem associated almost exclusively with the mining of coal in the Mullens area. Over 13 percent of the miners had some roentgenographic evidence of pneumoconiosis. Little was seen in the wives of the two groups, and only two cases were noted among nonminers. Radiologists reading these chest films had no knowledge of the occupation of the men whose films they saw, so there is no reason to suspect the kind of bias suggested by Braun [9] that might influence other types of studies of pneumoconiosis.

Mean values for forced expiratory volumes also suggest the presence of respiratory disease among miners not present among their wives or the nonminers examined. The distribution of values for 1-second forced expiratory volume divided by the total forced expiratory value (FEV_1/FEV) for miners was different from that of the nonminers (see also Section V). The similarity in mean FEV between wives of miners and wives of nonminers (Table 39) was surprising in view of the relatively higher frequency of most respiratory symptoms reported by wives of miners. Miners, on the other hand, had relatively low mean expiratory volumes, and their mean FEV_1/FEV was slightly below the percentage generally accepted as normal for men in this age group.[10] For more details, see Section V.

RESULTS OF MEDICAL EXAMINATIONS IN RICHWOOD

The household survey in Richwood was conducted in September and October 1964, and the medical examination in December 1964 and January and February 1965, or about 1 year after the Mullens study. Selected findings from the household interview are presented in Table 40. Response to the medical examination was not as good as at Mullens. Of 803 persons invited, 609, or 74.7 percent, responded. Of the 203 not responding, 146 refused and the remaining 57 had moved, died, or otherwise physically unable to report to the examination. A comparison of the prevalence of respiratory symptoms and other data from the household interviews between persons who responded and did not respond for the medical examination shows some differences (Table 40). Bias in Table 39 due to the absence

TABLE 40—*Comparison of selected results of household interviews from persons responding and not responding for medical examinations, Richwood.*

	Miners and their wives		Nonminers and their wives	
	Responding	Not responding	Responding	Not responding
Number of persons	331	90	269	113
Cough	47 (14.1)[a]	11 (12.3)	33 (12.2)	13 (11.6)
>3 mo >3 yr[b]	17 (5.1)	4	16 (5.9)	3
Phlegm	39 (11.7)	6 (6.7)	27 (10.3)	16 (14.1)
>3 mo >3 yr	15 (4.5)	4	10 (3.7)	2
Family income in past 12 months:				
Under $2,000	36 (10.9)	7 (7.8)	45 (16.7)	21 (18.6)
$2,000 to $4,000	66 (19.9)	20 (22.2)	96 (35.8)	40 (35.4)
$4,000 to $7,000	154 (46.5)	40 (44.4)	87 (32.3)	30 (26.5)
Over $7,000	60 (18.1)	15 (16.7)	25 (9.3)	13 (11.5)
Not ascertained	15 (4.6)	8 (8.9)	16 (5.9)	9 (8.0)
Education:				
8th grade or less	161 (48.6)	36 (40.0)	117 (43.4)	45 (39.8)
More than 8th grade	170 (51.3)	53 (58.8)	150 (55.7)	68 (60.1)
Not stated	0	1	2	0

[a] Percentage; percentages were not calculated for less than 5 cases.
[b] Cough present for most days for more than 3 months a year and for more than 3 years.

of those persons who failed to participate in the examination program is probably not very great however.

The mean age of miners responding for examinations was slightly lower than for nonminers, despite the attempt to match for age before the examination (Table 39). As in Mullens, the miners were slightly shorter, weighed less, and had cess of both cough and phlegm. Miners reported slightly more wheezing both with and without colds than nonminers, but there was no excess among miners' wives. Both miners and their wives reported more dyspnea grade 3 or worse than nonminers and their wives, but there was little difference in dyspnea grade 5. Miners and their wives both reported a history of pneumonia more miners, wives of miners had a slight excess of both cough and phlegm. Miners reported slightly more wheezing both with and without colds than nonminers, but there was no excess among miners' wives. Both miners and their wives reported more dyspnea grade 3 or worse than nonminers and their wives, but there was little difference in dyspnea grade 5. Miners and their wives both reported a history of pneumonia more frequently than nonminers and their wives, at or after the age of 18. Miners also show an excess of histories of pleurisy at age 18 or later.

As in Mullens, roentgenographic findings indicate a definite relationship between pneumoconiosis and coal mining, with women and nonminers evincing little or no evidence of the disease. Unlike the Mullens situation, however, forced expiratory volumes indicate no difference between coal miners and nonminers and are clearly within the limits of normal.[11]

A test of statistical significance at the 0.05 level applied to the raw frequency data in Table 39 shows that miners in Mullens reported significantly more cough and persistent cough, dyspnea (grade 3 or worse), and histories of pneumonia and pleurisy than nonminers. Miners' wives in Mullens reported significantly more phlegm production and persistent phlegm production, more wheezing without colds, more dyspnea (grade 3 or worse), and more histories of pneumonia than wives of nonminers. The Richwood miners reported significantly more histories of pneumonia over age 18 and more pleurisy than nonminers; however, their wives did not differ significantly from wives of nonminers for any of the variables presented. Adjustments made in percentages for differences in education levels between miners and nonminers in Mullens and for differences in cigarette smoking histories between wives of miners and wives of nonminers in Mullens and miners and nonminers in Richwood slightly alter these contrasts. Employing these adjustment procedures to generate theoretical frequencies and testing these frequencies for statistical significance reduce the contrast in persistent cough for men in Mullens and the contrast in phlegm production (any, or persistent) for women in Mullens to a level not quite statistically significant at the 0.05 level.

A summary of the results is presented in Table 41. Probably the most objective information obtained from both surveys was the data on chest roentgenograms and forced expiratory volumes. The roentgenograms show that coal mining had a significant effect ($P<0.05$) on men in both Mullens and Richwood with the effect considerably greater in Mullens. Forced expiratory volumes were significantly ($P<0.05$) affected by coal mining only among men in Mullens.

TABLE 41—*Excess of selected respiratory symptoms when miners and wives are compared with nonminers and wives.*

Symptom	Mullens		Richwood	
	Miners	Wives	Miners	Wives
Persistent cough	X [a]	X	....	X
Persistent phlegm	....	X	....	X
Wheezing	X	X *[b]	X	....
Dyspnea, grade 3 moderate or worse	X *	X *	X	X
Pneumonia	X *	X *	X *	X
Pleurisy	X *	....	X *	....
Pneumoconiosis	X *	....	X *	....
Low FEV_1	X *	....	....	....
Low FEV_1/FEV	X *	....	....	....

[a] X indicates excess.
[b] Asterisk indicates statistically significant difference, $P<0.05$. Some data are adjusted.

COMMENT

In Mullens, more miners had respiratory symptoms than did nonminers living in the area. At the outset, it was assumed that if the prevalence of symptoms among miners' wives was about the same as among wives of nonminers, any excess among miners could be attributed to coal mining, whereas if the prevalence among miners' wives was greater than among wives of nonminers, at least some of the excess was due to nonoccupational factors. The finding that wives of miners, like their husbands, had an excess of respiratory symptoms was not unexpected in view of previous studies. Occupational mortality statistics on bronchitis published by the Registrar General of England and Wales show excess mortality among coal miners' wives, and Higgins *et al.*, in studies of wives of coal miners, found an excess of respiratory symptoms.[7, 11] These findings apparently influenced a recent report by a committee of the British Medical Research Council in which it was concluded that the evidence, thus far, does not point to the inhalation of dust as a major factor in causing bronchitis. In the committee's report, an excess of bronchitis among coal miners was acknowledged, but the high prevalence among their wives was used as supportive evidence that general socioeconomic and environmental factors were causative agents rather than occupational factors.[12]

It may be that nonoccupational environmental factors are responsible for the excess in respiratory symptoms among miners in Mullens, and in designing this study, this was admittedly the alternative hypothesis. There are, however, other explanations. Possibly the excess prevalence among miners in some way contaminates their wives. There is some evidence to support a "contamination" hypothesis. First, British and other studies suggest that coal dust does indeed cause respiratory disease. For example, amount of years spent in coal mining shows a definite relationship to lung function, independent of age.[7] Thus, the excess prevalence of respiratory disease symptoms among miners may, indeed, be the result of exposure to coal dust. Secondly, the study by Higgins et al.[11] shows that the prevalence of cough or sputum or both and of chest illness was slightly higher in the wives of miners with reported symptoms than in the wives of miners without reported symptoms.

There are at least two ways in which miners with respiratory symptoms might contaminate their families. First, there may be a psychological contamination arising from observation by the family of respiratory symptoms in the miners. Thus, miners' wives may tend to report for themselves the symptoms that they observe in their husbands. This notion is supported by the normal expiratory volumes among miners' wives in Mullens but refuted by the excess mortality from bronchitis among coal miners' wives in England and Wales and by the low pulmonary function values observed in wives of British coal miners.

Secondly, chronic bronchitis may have an infectious aspect (in the bacteriological sense) and, thus, may, in effect, spread from husband to wife. An analogous situation would be excess tuberculosis among wives of workers with silicosis. This notion is supported by British mortality and statistics but does not explain the normal pulmonary function results among miners' wives in Mullens.

The contrast between the finding in Mullens and Richwood is not easily understood, although it might be related to differences in response to examination, to differences in exposure or in the type of coal mined in the two areas, or to some interaction with differing air pollution levels. Generally, residents of Richwood reported fewer respiratory symptoms and had better pulmonary function test results than residents of Mullens. Miners also had slightly shorter work histories in Richwood, averaging 19.2 years as compared with 22.3 years in Mullens.

Although the two community studies reported here have, thus far, provided no definitive answers to the question of the contribution of environmental exposures in coal mining to respiratory symptoms, they do raise some questions that deserve to be studied further. The answer to the question "Do environmental exposures in coal mining result in respiratory disease?" may be "Sometimes" depending upon the extent and type of exposure and upon other nonworking environmental conditions. The high prevalence of respiratory symptoms observed in this and other studies among miners' wives may, indeed, be the result of dust exposures on the part of their husbands if, in fact, contamination is a factor. Establishing whether this contamination is psychological or bacteriological would be of great importance.

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SECTION V

Ventilatory Function and Work Capacity in Appalachian Bituminous Coal Miners and Miners and Nonminers in Two West Virginia Communities

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Ventilatory Function and Work Capacity in Appalachian Bituminous Coal Miners and Miners and Nonminers in Two West Virginia Communities

AUSTIN HENSCHEL, Ph.D.

INTRODUCTION

To evaluate the ventilatory function in Appalachian bituminous coal miners, an integral part of the prevalence survey team was the pulmonary function team (usually two men) who accompanied the other members of the survey team. A house trailer, modified for use as a mobile pulmonary function laboratory, was utilized to perform the examinations, usually at the mine site. In the community studies, the ventilatory function equipment was transferred to empty stores. The following report emphasizes ventilatory function alone, ventilatory function and clinical findings referable to the chest in working miners, ventilatory function in working versus nonworking miners, and work capacity.

VENTILATORY FUNCTION

The basic pulmonary function test used in this pneumoconiosis prevalence survey was a forced vital capacity (FVC) test performed under rigidly standardized conditions. The test was given to four different groups of subjects:

(1) Coal miners who were working at the time of the prevalence survey (survey population),

(2) Nonworking coal miners who because of old age, disability, and other reasons were no longer mining at the time of the chest disease prevalence survey (survey population),

(3) A community group from Mullens, W. Va., comprised of working coal miners, railroad workers, and their wives, and

(4) A similar group derived from the community of Richwood, W. Va., comprised of working coal miners, men of other occupations, and their wives.

The ventilatory function test equipment consisted of a Wedge Spirometer Model 170 and a Sanborn Dual Channel Recorder Model 296. These apparatus provide a record of timed expiratory volume and of expiratory flow rate. FVC measurements were made with the subject seated in a chair. In every instance, the chair height was adjusted so that, when the subject was sitting up straight, his feet were flat on the floor and his upper legs were parallel to the floor.

When the subject was properly seated, the procedure for a forced vital capacity measurement was explained and demonstrated. The subject was then asked to follow the test procedure for practice. After a brief rest, three forced expiratory maneuvers were performed with the subject being instructed to make a maximum inspiration and then to exhale as fast and as hard as possible. After the three forced expirations were recorded, the subject rested a few minutes and then took 10 normal breaths through a two-way valve and mouthpiece from a bag containing 80 percent helium and 20 percent oxygen. This gas mixture replaced the normal atmospheric mixture of nitrogen, oxygen, and carbon dioxide in the lungs. Another forced vital capacity maneuver was then performed with the inspirations of the $He\text{-}O_2$ mixture. The reason for using this lighter than air $He\text{-}O_2$ mixture is that it should be more readily expired in individuals with increased resistance to air flow.

From the technically best of the three FVC tracings, data were derived for the total FVC, for the forced expiratory volume at 1, 2, and 3 seconds (FEV_1, FEV_2, and FEV_3) and for FEV_1, FEV_2, and FEV_3 values expressed as percent of the total FVC. These values were calculated for the lungs filled with the normal atmospheric mixture (without helium) and for the lungs filled with the $He\text{-}O_2$ mixture. On the basis of mean age and

TABLE 42—*Mean age, height, and weight of miners, nonminers, and wives.*

Survey groups	Working miners			Nonworking miners and others			Wives		
	Age group								
	<40	40–50	>50	<40	40–50	>50	<40	40–50	>50
Age, years:									
Richwood	33 (5)[a]	44 (3)	56 (4)	31 (6)	45 (3)	57 (4)	32 (5)	45 (3)	55 (3)
Mullens	33 (5)	45 (3)	55 (3)	32 (5)	46 (3)	57 (4)	32 (5)	45 (3)	55 (4)
Survey	33 (5)	45 (3)	56 (4)	36 (2)	46 (3)	60 (4)			
Height, centimeters:									
Richwood	176 (7)	175 (6)	175 (6)	178 (5)	175 (6)	175 (7)	164 (5)	164 (7)	163 (6)
Mullens	176 (6)	175 (6)	174 (7)	178 (6)	177 (6)	175 (6)	162 (6)	163 (6)	162 (6)
Survey	176 (6)	176 (7)	174 (7)	176 (7)	175 (6)	173 (7)			
Weight, kilograms:									
Richwood	76.2 (11.4)	72.8 (10.1)	75.5 (11.7)	76.5 (14.3)	75.4 (11.9)	74.7 (11.4)	62.5 (10.7)	65.7 (12.7)	67.0 (14.8)
Mullens	78.6 (11.2)	76.2 (9.0)	72.0 (11.1)	81.8 (14.2)	78.7 (11.7)	78.7 (13.4)	60.6 (11.2)	69.4 (15.2)	65.2 (11.9)
Survey	76.7 (11.4)	80.2 (33.2)	77.7 (21.7)	75.9 (12.9)	76.2 (14.4)	74.8 (13.1)			

[a] Standard deviation.

height, the "normal" predicted values were calculated from the Guides to the Evaluation of Permanent Impairment of the Respiratory System (AMA Guides)[1] for the various subject groupings. All values were calculated for air at ambient temperature and pressure and saturated with water vapor.

Because some physiological functions change slowly with age, each of the four groups of subjects was subdivided into three age categories: less than 40 years of age, 40 through 50 years of age, and over 50 years of age. Among the working miners in the prevalence survey, complete ventilatory measurements were obtained from 2,432 men: 579 (25 percent) were less than 40 years of age; 1,014 (40 percent) were 40 to 50 years of age, and 839 (35 percent) were over 50 years of age. Among the nonworking miners in the prevalence survey, complete ventilatory measurements were obtained from 1,028 men: 30 (3 percent were less than 40 years of age; 129 (12 percent) were 40 to 50 years of age, and 869 (85 percent) were over 50 years of age. These complete measurements were not obtained from the entire working miner survey group (2,549) or nonworking miner survey group (1,191) discussed in Section III because of noncooperation or unavailability of subjects, unsatisfactory measurements, or equipment failure.

The demographic data for the four groups of subjects arranged according to the three age categories are given in Table 42. The groups were very similar in height, weight, and age except the nonworking miners over 50 years of age in the survey groups were on the average older and shorter than the other groups of men in the same age category.

Normal predicted pulmonary function values calculated according to the AMA Guides[1] are presented in Table 43 for the FVC, the 1-second forced expiratory volume (FEV_1), and the percentage of the FVC expired during the first second (FEV_1/FVC). The values were calculated separately for the three age categories of the working miners and nonworking miners who comprised the pneumoconiosis prevalence survey groups, and for the miners, nonminers, and wives in the community studies at Richwood and Mullens. The calculated values form the basis against which the data obtained during the study are compared for estimating the normality of ventilatory function in the several population groups. In the following discussions, the various population groups will be treated separately.

Pneumoconiosis Prevalence Survey

Ventilatory function data of the working miners and the nonworking miners included in the pneumoconiosis prevalence survey (Tables 44 and 45, Figure 24) were obtained for 2,432 working miners and 1,028 nonworking miners. The nonworking miners were not working for health or age reasons, were unemployed, or were working at other than coal mining jobs.

The observed mean FVC both without and with helium breathing was close to the values predicted from the AMA Guides[1] (Table 43). For the non-

TABLE 43—*Mean observed and predicted ventilatory functions of working miners and nonworking miners.*

Ventilatory function	Working miners			Nonworking miners		
	Age group					
	<40	40–50	>50	<40	40–50	>50
FVC[a] observed	4.57	4.29	3.90	4.27	3.82	3.43
FVC predicted	4.53	4.28	3.96	4.47	4.21	3.82
FEV_1 observed	3.49	3.20	2.78	3.20	2.68	2.31
FEV_1 predicted	3.70	3.39	3.04	3.62	3.33	2.90
FEV_1/FVC observed	76	74	71	74	69	67
FEV_1/FVC predicted	82	79	77	81	79	76

[a] Abbreviations used:

FVC —Forced vital capacity
FEV_1 —Forced expiratory volume, 1 second
FEV_2 —Forced expiratory volume, 2 seconds
FEV_3 —Forced expiratory volume, 3 seconds
FEV_1 He—FEV_1 with helium
FEV_2 He—FEV_2 with helium
FEV_3 He—FEV_3 with helium

FVC, FEV_1, FEV_2, FEV_3, FEV_1 He, FEV_2 He, FEV_3 He — Value in liters

FEV_1/FVC, FEV_2/FVC, FEV_3/FVC, FEV_1 He/FVC, FEV_2 He/FVC, FEV_3 He/FVC — Value in per cent

TABLE 44—*Predicted values [a] for total forced vital capacity (FVC), 1-second forced expiratory volume (FEV_1), and percentage of FVC expired during the first second of a forced expiration (FEV_1/FVC) for all groups surveyed*

Survey groups	Miners			Nonworking miners and nonminers			Wives		
	Age group								
	<40	40–50	>50	<40	40–50	>50	<40	40–50	>50
Richwood:									
FVC [b]	4.53	4.25	4.01	4.66	4.23	3.99	3.20	2.98	2.78
FEV_1	3.70	3.38	3.07	3.82	3.35	3.04	2.83	2.57	2.35
FEV_1/FVC	82	80	77	82	79	76	88	86	85
Mullens:									
FVC	4.53	4.23	3.98	4.64	4.31	3.99	3.12	2.95	2.74
FEV_1	3.70	3.35	3.06	3.80	3.40	3.04	2.78	2.54	2.33
FEV_1/FVC	82	79	77	82	79	76	89	86	85
Survey:									
FVC	4.53	4.28	3.96	4.47	4.21	3.82	...	...	...
FEV_1	3.70	3.39	3.04	3.62	3.33	2.90	...	...	...
FEV_1/FVC	82	79	77	81	79	76	...	...	...

[a] Calculated for age groups from the Journal of the American Medical Association Guides.[1]
[b] Abbreviations used: see Table 43.

working miners in the 40 to 50 and over 50 years of age groups, the mean FVC was about 10 percent lower than the predicted value. This small difference is within the range of intragroup variability. As expected, no difference between FVC without and with helium was present, since helium should not change the total lung volume. The closeness of the values did serve as a check on the repeatability of the procedure, which appeared to be excellent.

The observed FEV_1 values deviated further from the predicted values than did the total FVC values. All age groups of both the working miners and the

TABLE 45—*Mean ventilatory function data, with and without helium breathing, for survey working and nonworking miners*

Ventilatory function	Working miners <40		Working miners 40–50		Working miners >50		Nonworking miners <40		Nonworking miners 40–50		Nonworking miners >50	
Age, years	33	(5) [a]	45	(3)	56	(4)	36	(2)	46	(3)	60	(4)
Height, centimeters	176	(6)	176	(7)	174	(7)	176	(7)	175	(6)	173	(7)
Weight, kilograms	76.7	(11.4)	78.4	(12.1)	77.7	(12.1)	75.9	(12.9)	76.2	(14.4)	74.8	(13.1)
FVC,[b] no He	4.57	(0.76)	4.29	(0.71)	3.90	(0.75)	4.27	(0.56)	3.82	(0.90)	3.43	(0.83)
FEV_1, no He	3.49	(0.78)	3.20	(0.70)	2.78	(0.73)	3.20	(0.78)	2.68	(0.97)	2.31	(0.78)
FEV_2, no He	4.18	(0.77)	3.80	(0.70)	3.35	(0.72)	3.90	(0.68)	3.32	(0.94)	2.87	(0.81)
FEV_3, no He	4.38	(0.75)	4.03	(0.69)	3.59	(0.72)	4.12	(0.61)	3.57	(0.92)	3.12	(0.81)
FVC, He	4.51	(0.78)	4.28	(0.70)	3.92	(0.73)	4.33	(0.78)	3.78	(0.94)	3.41	(1.06)
FEV_1, He	3.58	(0.87)	3.31	(0.76)	2.94	(0.75)	3.27	(0.83)	2.78	(0.98)	2.42	(1.04)
FEV_2, He	4.19	(0.79)	3.86	(0.71)	3.44	(0.74)	3.99	(0.73)	3.36	(0.96)	2.92	(1.05)
FEV_3, He	4.37	(0.78)	4.06	(0.70)	3.66	(0.72)	4.19	(0.74)	3.58	(0.94)	3.14	(1.04)
FEV_1/FVC	76	(12)	74	(11)	71	(12)	74	(14)	69	(16)	67	(14)
FEV_2/FVC	90	(7)	88	(7)	85	(8)	89	(7)	86	(11)	82	(11)
FEV_3/FVC	94	(4)	93	(5)	91	(6)	94	(4)	91	(8)	89	(8)
FEV_1 He/FVC	79	(13)	77	(12)	74	(12)	75	(13)	72	(15)	70	(15)
FEV_2 He/FVC	91	(7)	89	(7)	87	(9)	91	(6)	88	(10)	84	(11)
FEV_3 He/FVC	95	(4)	93	(5)	92	(6)	95	(3)	93	(7)	90	(8)

[a] Standard deviation.
[b] Abbreviations used: see Table 43.

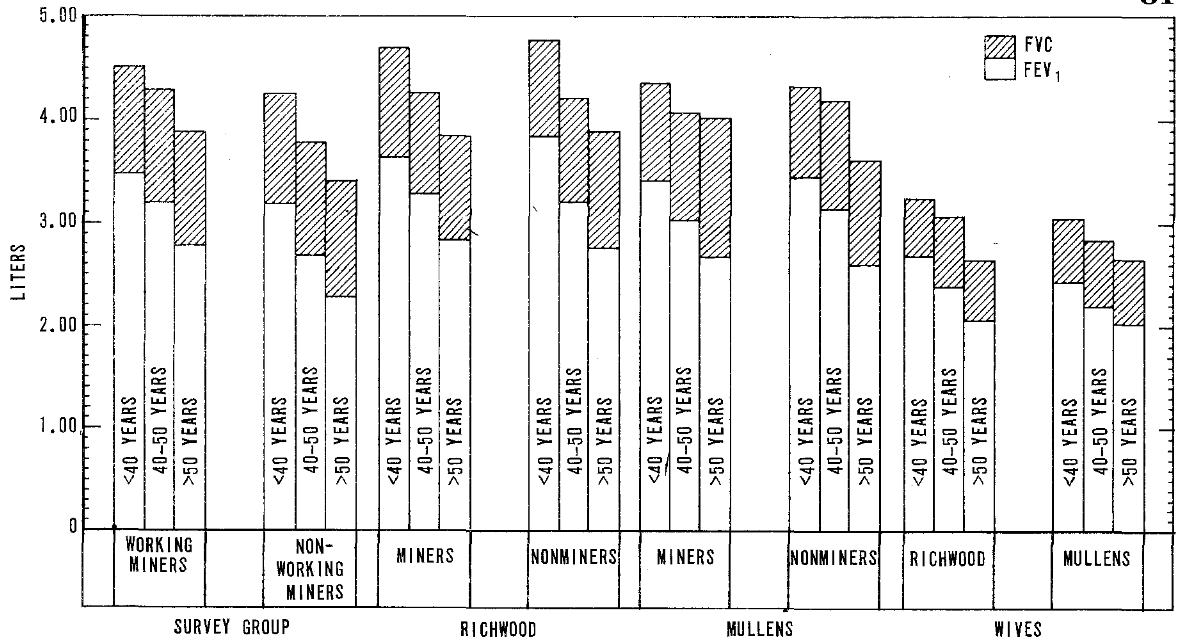

Figure 24.—Forced vital capacity and 1-second forced expiratory volume for all groups surveyed

nonworking miners had lower than predicted mean FEV_1 values (Table 43). The average decrease was from 6 to 9 percent in the working miners, which is within the normal range of variability, and 12 to 20 percent in the nonworking miners. The values for these working coal miners were generally higher than those observed in metal miners.[2] An individual FEV_1 value 15 percent below the normal predicted value is classed as borderline normal by the AMA Guides [1] standards. The mean FEV_1 values observed in both the 40 to 50 and over 50 years of age groups of the nonworking miners falls within the 20 percent impairment criteria. For these two age groups, the same indications of decreased ventilatory function were also seen in the observed FEV_1/FVC ratio. A FEV_1/FVC below 70 percent is considered to indicate an impairment of ventilatory capacity.[1]

The decrease in FEV_1 with a normal FVC would indicate some degree of air flow resistance, particularly in the two older age groups of the nonworking miners. The concept that the air flow resistance is increased is further strengthened by the fact that the FEV_1 with the He-O_2 mixture was slightly but consistently higher than the FEV_1 when the normal atmospheric gas mixture was used. The average increase was, however, only about 3 to 4 percent. An interpretation of the meaning of the quantitative changes in flow rate with He-O_2 gas mixture in terms of overall pulmonary function is not possible at present.

Community Studies

As discussed in Sections II and IV, the community studies at Richwood and Mullens were not specifically designed to furnish data on the prevalence of pneumoconiosis in coal miners. The studies do, however, provide bases for comparing a working coal mining population with workers in other industries of the same community and for describing ventilatory function in wives of miners and nonminers living under similar extra-industrial conditions.

Of the 600 participants in the Richwood community study, a total of 580 had ventilatory function tests: 260 housewies, 171 male miners, and 149 male nonminers. Richwood is located in the northern part of West Virginia where chest disorders are reported to be less prevalent than in the southern areas of the State. The ventilatory function data are given in Table 46 and Figure 24 for the male miners, nonminers, and females. No consistent or statistically significant differences were observed between the miners and nonminers for any of the ventilatory function parameters measured, and when compared with the calculated "normal" predicted values (Table 43), no significant deviations were found. A slightly but consistently larger FEV_1

TABLE 49—*Mean ventilatory function related to cigarette smoking and bronchitis for working miners*

Ventilatory function	Number of cigarettes smoked daily						Severity of bronchitis					
	None		<20		20 or more		None		Simple		Multiple	
Age, years	47	(10)[a]	46	(9)	46	(9)	46	(9)	46	(10)	48	(8)
Height, centimeters	175	(7)	175	(7)	176	(7)	175	(7)	174	(5)	175	(6)
Weight, kilograms	81	(13)	76	(12)	77	(12)	78	(12)	73	(11)	78	(12)
FVC,[b] observed	4.24	(0.78)	4.22	(0.78)	4.20	(0.77)	4.23	(0.77)	4.00	(0.79)	4.10	(0.81)
FVC, predicted	4.33		4.35		4.35		4.35		4.35		4.30	
FVC, percent observed of predicted	98		97		96		97		92		95	
FEV_1, observed	3.22	(0.81)	3.12	(0.78)	3.06	(0.74)	3.14	(0.77)	2.86	(0.83)	2.92	(0.90)
FEV_1, predicted	3.40		3.42		3.42		3.42		3.42		3.37	
FEV_1, percent observed of predicted	95		91		89		92		84		87	
FEV_1/FVC, percent observed	75	(12)	74	(12)	73	(12)	74	(11)	71	(12)	70	(14)
FEV_1/FVC, percent predicted	79		79		79		79		79		78	
FEV_1/FVC, percent observed of predicted	96		94		92		94		90		89	

[a] Standard deviation.
[b] Abbreviations used: see Table 43.

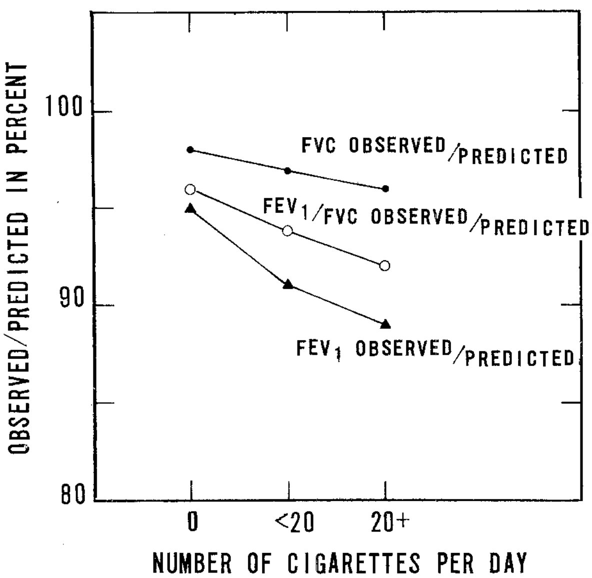

Figure 26.—The observed as percent of the predicted values for forced vital capacity, 1-second forced expiratory volume (FEV_1), and FEV_1/FVC related to number of cigarettes smoked daily

tions pertaining to frequency of episodes. On the basis of the number, severity, and frequency of reported episodes of bronchitis, the individuals were classed as "none," "simple," or "multiple". Of the 2,405 working miners upon whom complete ventilatory function data and bronchitis history were obtained, only 45 (2.0 percent) of the miners were classified in the "simple" category and 109 (4.5 percent) in the "multiple" category. The remaining 2,251 had no symptoms of bronchitis. The pertinent data comparing ventilatory function and severity of bronchitis are presented in Table 49 and Figure 27.

It is noteworthy that the severity of bronchitis as determined by the medical history questionnaire was not directly related to age (Table 49). If bronchitis resulted from the dust and irritants in the working environment, a greater prevalence of bronchitis symptoms would be expected in the older miners who had worked longest underground. Extent of impairment in ventilatory function, also, was not consistent with the severity of bronchitis. For the group with simple bronchitis, the observed FEV_1 and FEV_1/FVC values were lower than in the "none" group, whereas the "multiple" group was about the same as the "simple" group. When all individuals who have experienced episodes of bronchitis are compared with those who have had none, the bronchitis group exhibits a distinct reduction in observed FEV_1 and FEV_1/FVC values with relatively comparable FVC values. Surprisingly, however, the frequency of symptoms of bronchitis is not reflected in comparable alterations in those phases of pulmonary function that were measured. Possibly those reporting bronchitis did not correctly recall the frequency and severity of their episodes. The number of individuals in the "simple" bronchitis group was small.

Ventilatory Function and Dyspnea

The definitions of the categories of dyspnea and the occurrence of the symptomatology among the working miners and nonworking miners were developed in Section III. The data relating the degree of dyspnea and several aspects of ventilatory function are presented in Table 50 and Figure 28. Of the 2,422 miners for whom complete ventilatory function data and degree of dyspnea were obtained, 1,140 had no dyspnea, 1,199 had moderate dyspnea, and 83 had marked dyspnea. The miners who had no symptoms of dyspnea were, on the average, 4 years younger than those who had a slight to moderate degree, and those, in

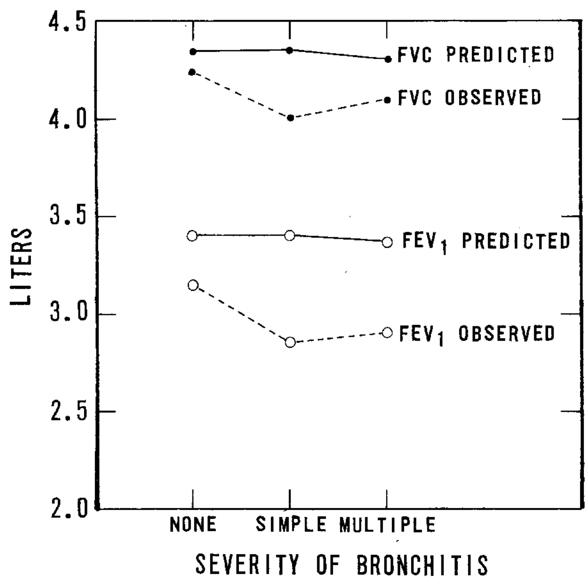

Figure 27.—Observed and predicted values for forced vital capacity (FVC) and 1-second forced expiratory volume (FEV_1) related to the severity of bronchitis

TABLE 50—*Mean ventilatory function related to dyspnea and roentgenographic categories for working miners*

Ventilatory function	Degree of dyspnea						Roentgenographic category							
	None to slight		Moderate		Marked and severe		Negative		Suspect		Simple		Complicated	
Age, years	44	(9) [a]	48	(9)	51	(9)	45	(9)	50	(8)	51	(7)	53	(7)
Height, centimeters	176	(7)	175	(6)	174	(7)	176	(7)	176	(6)	175	(7)	175	(6)
Weight, kilograms	78	(12)	78	(12)	75	(11)	78	(12)	78	(12)	75	(10)	71	(10)
FVC,[b] observed	4.34	(0.74)	4.14	(0.79)	3.76	(0.81)	4.25	(0.78)	4.05	(0.79)	4.05	(0.78)	4.17	(0.75)
FVC, predicted	4.39		4.30		4.24		4.37		4.26		4.24		4.20	
FVC, percent observed of predicted	99		96		89		97		95		95		99	
FEV_1, observed	3.28	(0.73)	3.02	(0.78)	2.46	(0.82)	3.16	(0.78)	2.96	(0.78)	2.94	(0.72)	2.84	(0.76)
FEV_1, predicted	3.48		3.37		3.29		3.45		3.32		3.29		3.24	
FEV_1, percent observed of predicted	94		90		74		92		89		89		88	
FEV_1/FVC, percent observed	75	(11)	73	(12)	65	(16)	74	(12)	73	(12)	72	(11)	68	(13)
FEV_1/FVC, percent predicted	79		78		78		79		78		78		77	
FEV_1/FVC, percent observed of predicted	95		93		84		94		94		93		89	

[a] Standard deviation.
[a] Abbreviations used: see Table 43.

turn, were 3 years younger than those with marked and severe dyspnea. That severe dyspnea increases with the average age is a generally accepted fact. Such dyspneic impairment reflects inadequacies in the cardio-respiratory system, and an age correction factor is included in formulas for calculating ventilatory function. In the miners included in this study, about 47 percent reported no symptoms of dyspnea, 49 percent had slight to moderate dyspnea, and only about 4 percent had marked and severe dyspnea.

The observed FVC was within 50 cubic centimeters of the predicted values for the none or slightly dyspneic group and within 160 cubic centimeters for the group with moderate dyspnea, but was 480 cubic centimeters less than the predicted for the marked and severe dyspnea group. The greater reduction of FEV_1 with increase in dyspnea was striking: 200 cubic centimeters for none or slight group; 350 for the moderate group; and 830 for the marked and severely dyspneic group. The 830 cubic centimeter reduction in FEV_1 was equal to one standard deviation of the

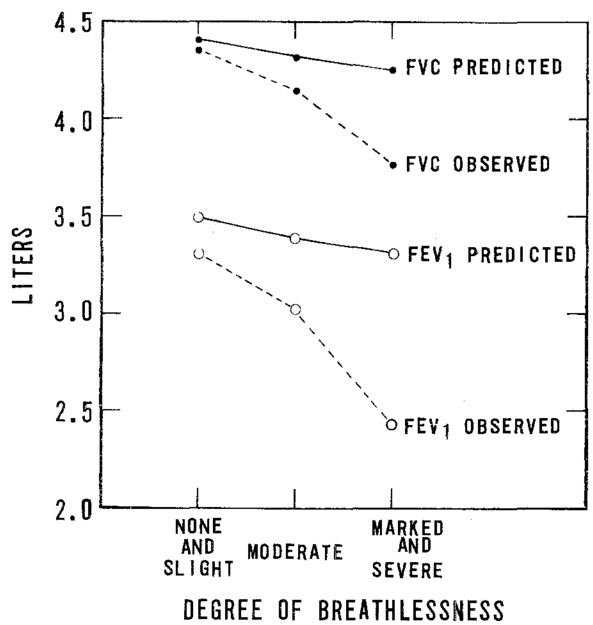

Figure 28.—Observed and predicted values for forced vital capacity (FVC) and 1-second forced expiratory volume (FEV_1) as related to degree of dyspnea

mean of the observed values. As shown in Table 50, the observed FEV_1 for the marked and severe dyspneic group was only 74 percent of the predicted value (normal should be 85 percent or more) and the observed FEV_1/FVC was only 65 percent (normal is 70 percent or over). When corrected for the age factor, the marked and severe dyspneic group had significant impairment of the ability to move air out of the lungs. This was probably associated with increased airway resistance.

Ventilatory Function and Roentgenographic Categories

The roentgenographic technique and findings are described under Roentgenographic Findings in Section III. The data on the relationships between the roentgenographic categories indicative of pneumoconiosis and ventilatory functions are given in Table 50 and Figure 29. Complete pulmonary function data and roentgenographic interpretations were obtained on 2,418 men, with 2,053 in the negative category, and 130 in the suspect, 164 in the simple, and 71 in the complicated pneumoconiotic roentgenographic categories. A direct comparison of the ventilatory function data among these four roentgenographic categories is not possible because of an age trend. The men comprising the roentgenographic categories that denoted greater lung tissue involvement were also older. The age factor, however, may be accounted for by comparing the observed and the age-corrected predicted values for each roentgenographic category.

The FVC was relatively normal in all four roentgenographic categories. The FEV_1 was depressed in all categories with the depression being greater in those showing greater lung tissue involvement. No differences were seen between the suspect pneumoconiosis and simple pneumoconiosis categories. The FEV_1 was least depressed in the negative category, intermediate in the suspect pneumoconiosis and simple pneumoconiosis categories, and most depressed in the complicated pneumoconiosis category. The reduction in ventilatory capacity reflecting increased airway resistance was particularly striking in the complicated pneumoconiosis group. There, the mean observed FEV_1/FVC value was only 68 percent; normal values should be greater than 70 percent.[1]

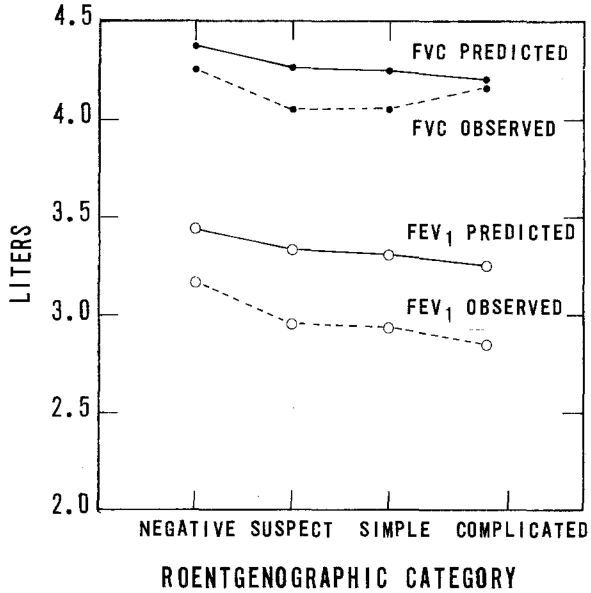

Figure 29.—Observed and predicted values for forced vital capacity (FVC) and 1-second forced expiratory volume (FEV_1) related to degree of lung changes indicative of pneumoconiosis exhibited on the roentgenograms

VENTILATORY FUNCTION: WORKING MINERS VERSUS NONWORKING MINERS

This part of the report on ventilatory function compares the pulmonary function (FVC and FEV_1/) aspects of working and nonworking miners as related to years of underground working experience, cigarette smoking history, symptoms of bronchitis, reported extent of dyspnea, and pneumoconiotic roentgenographic categories. In addition, working and nonworking miners with a FEV_1/FVC ratio of 70 percent or more are compared with those having a FEV_1/FVC of less than 70 percent. The 70 percent division point is based on the AMA Guides[1] suggestion that a FEV_1/FVC less than 70 percent indicates pulmonary function impairment.

Years of Working Underground

Only those men whose mining experience was principally underground were included in this comparative study: 2,062 working miners and 917 nonworking miners. The FEV_1/FVC was 70 percent or above for 1,476 (72 percent) of the working miners and for 454 (50 percent) of the nonworking miners. It was less than 70 percent for 586 (28 percent) working miners and 463 (50 percent) nonworking miners. The FVC and FEV_1 values as a function of years of underground experience are presented for the working miners (Table 51 and Figure 30) and for the nonworking miners (Table 51 and Figure 31).

There are several striking differences between the working and nonworking miners. About 25 percent of the working miners have a FEV_1/FVC of less than 70 percent whereas 50 percent of the nonworking miners are in the depressed function category. The percentage of working miners with FEV_1/FVC of less than 70 percent increased with experience underground from 16 percent for less than 10 years, 22 percent for 10 to 19 years, 28 percent for 20 to 29 years until it reached 38 percent for 30 years or longer. A ventilatory function impairment was found in 34 percent of the nonworking miners having less than 20 years underground experience, 49 percent with 20 to 29 years, and 55 percent for over 30 years.

The nonworking miners in each comparable grouping of years underground averaged 6 to 9 years older than the working miners. This age difference is illustrated in the predicted FVC and FEV_1 values (Figures 30 and 31). The nonworking miners were similar in height to the working miners but were 5 to 10 pounds lighter. This may be due to the overall health status of the nonworking miners that was, on the average, not as satisfactory as that of the working miners.

A comparison of Figures 30 and 31 shows that FVC and FEV_1 values are about 500 cubic centimeters lower in the nonworking miners than in the working miners. Moreover, the values are strikingly lower than the predicted values for the nonworking miners. For the working miners, the observed and predicted FVC and FEV_1 values are similar except that the FEV_1 is significantly reduced for the group whose FEV_1/FVC is less than 70 percent.

The progressive decrease in observed FVC and FEV_1 values for both working and nonworking miners with increase in years of underground working experience roughly parallels the decrease in the predicted values. The decrease, therefore, appears to be mainly a function of age. When allowance is made for age differences, however, some relation between years of working underground and depression of ventilatory function is present.

TABLE 51—*Ventilatory function related to number of years of underground mining experience for all working and nonworking miners, those with a FEV_1/FVC of 70 percent and above, and those with FEV_1/FVC less than 70 percent.*

Ventilatory function	Years underground							
	<10		10–19		20–29		30+	
	Working	Nonworking	Working	Nonworking	Working	Nonworking	Working	Nonworking
All working and nonworking miners:								
Age, years	31	45	40	47	47	56	55	61
Height, centimeters	176	175	176	174	175	175	174	173
Weight, kilograms	75	70	78	74	79	74	77	75
FVC [a], observed	4.73	4.15	4.36	3.75	4.18	3.54	3.92	3.41
FVC, predicted	4.70	4.37	4.47	4.30	4.33	4.14	4.12	3.94
FEV_1, observed	3.65	2.66	3.29	2.75	3.06	2.37	2.79	2.27
FEV_1, predicted	3.85	3.45	3.62	3.37	3.40	3.17	3.25	2.98
FEV_1/FVC	77	64	75	73	73	67	71	67
Miners with FEV_1/FVC 70 percent and above:								
Age, years	31	47	40	45	47	56	55	61
Height, centimeters	177	176	176	174	175	173	173	173
Weight, kilograms	76	76	79	78	79	75	79	77
FVC	4.76	4.48	4.38	3.95	4.24	3.63	4.00	3.54
FEV_1	3.84	3.30	3.49	3.19	3.33	2.82	3.12	2.73
FEV_1/FVC	81	74	80	81	79	78	78	77
Miners with FEV_1/FVC less than 70 percent:								
Age, years	31	43	40	52	48	55	56	61
Height, centimeters	176	174	175	173	174	176	174	173
Weight, kilograms	71	66	74	72	75	73	74	73
FVC	4.55	3.91	4.31	3.36	4.04	3.44	3.78	3.30
FEV_1	2.64	2.18	2.56	1.87	2.39	1.90	2.25	1.87
FEV_1/FVC	58	56	59	56	59	55	59	57

[a] Abbreviations used: see Table 43.

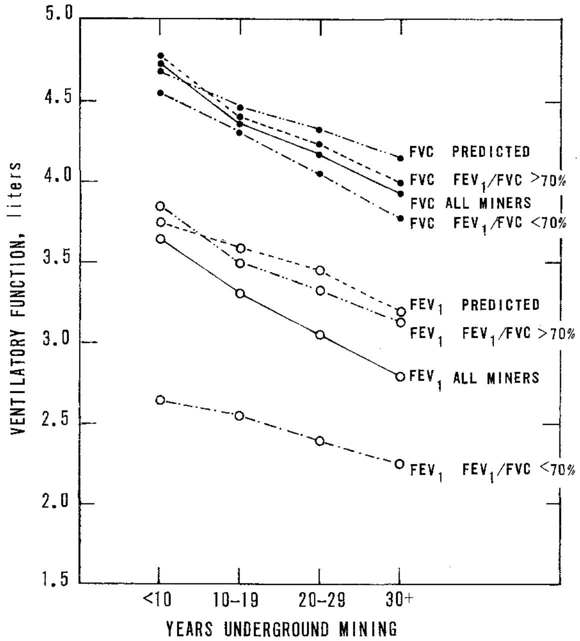

Figure 30.—Average forced vital capacity (FVC) and 1-second forced expiratory volume (FEV_1) for all working miners, working miners with FEV_1/FVC 70 percent and above, working miners with FEV_1/FVC less than 70 percent, and predicted values related to years of underground mining experience as principal occupation

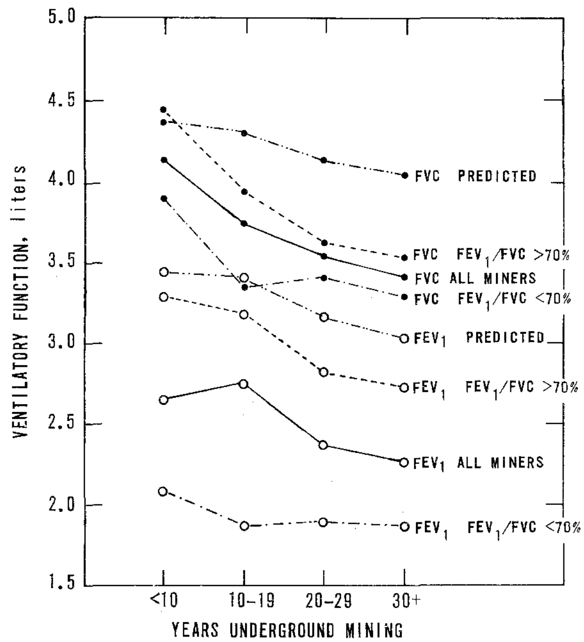

Figure 31.—Average forced vital capacity (FVC) and 1-second forced expiratory volume (FEV_1) for all nonworking miners, nonworking miners with FEV_1/FVC 70 percent and above, nonworking miners with FEV_1/FVC less than 70 percent, and predicted values related to years of underground mining experience as principal occupation

Cigarette Smoking History

Data are presented for the relationship between the number of cigarettes smoked each day and the observed FVC and FEV_1 values for 2,433 working miners (Table 52 and Figure 32) and for 1,029 nonworking miners (Table 52 and Figure 33).

The FVC and FEV_1 depression in the nonworking miners is on the average about 500 cubic centimeters greater than that of the working miners, when corrected for the differences in age and height. The nonworking miners are about 10 years older and one-half an inch shorter than the working miners. The number of cigarettes smoked each day did not appear to influence the ventilatory function status of either the working or nonworking miners.

There was no difference in the proportion of working and nonworking miners who did not smoke. About 25 percent did not smoke, 50 percent smoked less than 20 cigarettes a day, and 25 percent smoked a pack or more daily. The average nonsmoker differed from the smoker only by being about 10 pounds heavier.

Bronchitis

The relationship between reported symptoms of bronchitis and ventilatory function are given for the working miners (Table 53 and Figure 34) and for the nonworking miners (Tables 53 and Figure 35). The working miners averaged about 12 years younger, three-fourth inch taller, and 5 pounds heavier than the nonworking miners. The nonworking miners again showed a depression of ventilatory function. Of the 2,405 working miners with ventilatory function data and a bronchitis history, 45 were classified as having "simple bronchitis" and 109 as having "multiple bronchitis." Of the 1,017 nonworking miners, 31 had "simple" and 103 had "multiple" bronchitis.

Neither FVC or the FEV_1 showed any consistent relationship to the severity of symptoms of bronchitis in either the working miners or the

TABLE 52—*Ventilatory function related to cigarette smoking for all working and nonworking miners, those with FEV_1/FVC of 70 percent and above, and those with FEV_1/FVC, less than 70 percent.*

Ventilatory function	Number of cigarettes smoked daily					
	None		<20		20+	
	Working	Nonworking	Working	Nonworking	Working	Nonworking
All working and nonworking miners:						
Age, years	47	59	46	57	46	57
Height, centimeters	174	172	175	174	175	173
Weight, kilograms	81	79	76	73	77	76
FVC,[a] observed	4.24	3.57	4.22	3.47	4.21	3.54
FVC, predicted	4.30	3.96	4.35	4.08	4.35	3.98
FEV_1, observed	3.21	2.56	3.12	2.30	3.06	2.39
FEV_1, predicted	3.36	2.98	3.42	3.10	3.42	3.08
FEV_1/FVC	76	72	74	66	73	67
Miners with FEV_1/FVC 70 percent and above:						
Age, years	46	59	45	57	45	56
Height, centimeters	175	172	175	173	175	173
Weight, kilograms	83	79	77	76	78	77
FVC	4.33	3.64	4.30	3.66	4.23	3.68
FEV_1	3.48	2.87	3.41	2.84	3.32	2.87
FEV_1/FVC	80	79	79	78	78	79
Miners with FEV_1/FVC less than 70 percent:						
Age, years	49	59	49	58	47	59
Height, centimeters	173	172	175	174	176	173
Weight, kilograms	76	77	73	71	75	75
FVC	3.95	3.42	4.02	3.30	4.17	3.41
FEV_1	2.31	1.98	2.40	1.84	2.47	1.93
FEV_1/FVC	58	58	60	56	59	57

[a] Abbreviations used: see Table 43.

nonworking miners. In fact, for both groups the greatest depression of FVC and FEV_1 was observed in the men who had symptoms of "simple" bronchitis. This may be done to the small number of men who made up the "simple" bronchitis group (76 out of 3,422 men for whom bronchitis information was available).

Dyspnea

Dyspnea was a common complaint among both working and nonworking miners; about 53 percent of the working miners and 84 percent of the nonworking miners reported moderate or marked and severe dyspnea (See Section III.) The degree of dyspnea was more severe in nonworking miners; 3 percent of the working and 36 percent of nonworking miners reported marked and severe dyspnea. The relationships between the extent of dyspnea and FVC and FEV_1 is presented for 2,433 working miners (Table 54 and Figure 36) and 1,029 nonworking miners (Table 54 and Figure 37).

As in other comparisons, the nonworking miners were older than the working miners and about one-half inch shorter, but of the same weight. As shown in Figures 36 and 37, the predicted FVC and FEV_1 were about 400 cubic centimeters lower in the nonworking miners than in the working miners.

The average differences in the observed FVC and FEV_1 between the working and nonworking miners who had no or slight symptoms of dyspnea was about 500 cubic centimeters; for those with marked and severe dyspnea the difference was about 600 cubic centimeters. A comparison of the predicted and observed values in the working miners with moderate dyspnea revealed that the FVC was reduced 190 cubic centimeters and the FEV_1 was reduced 380; the corresponding values were 490 cubic centimeters and 660 cubic centimeters for the working miners with marked and severe dyspnea. The differences between the predicted and observed values for the nonworking miners with moderate dyspnea was 370 and 530

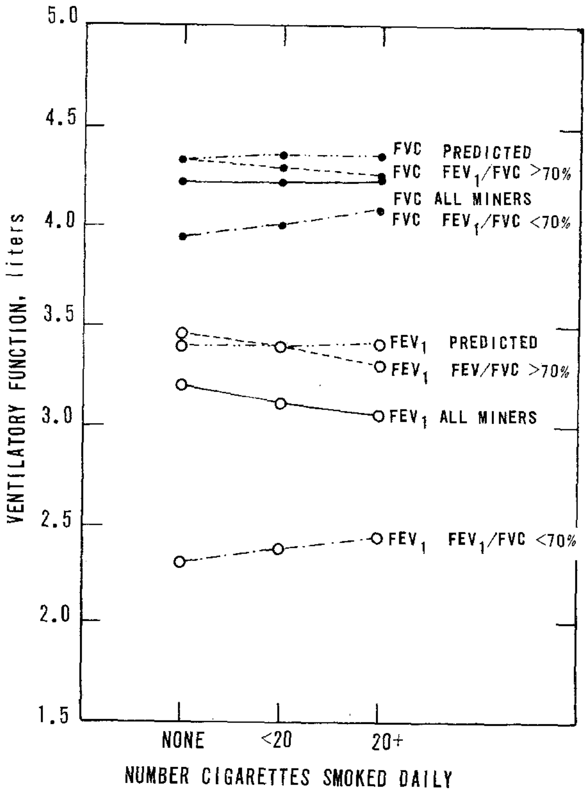

Figure 32.—Average forced vital capacity (FVC) and 1-second forced expiratory volume (FEV_1) for all working miners, working miners with FEV_1/FVC 70 percent and above, working miners with FEV_1 /FVC less than 70 percent, and predicted values related to cigarette smoking

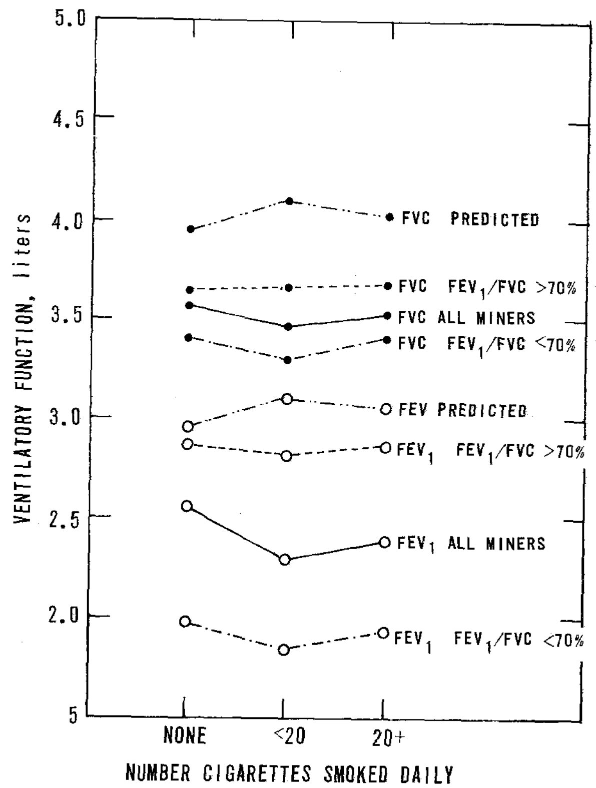

Figure 33.—Average forced vital capacity (FVC) and 1-second forced expiratory volume (FEV_1) for all nonworking miners, nonworking miners with FEV_1/FVC 70 percent and above, nonworking miners with FEV_1/FVC less than 70 percent, and predicted values related to cigarette smoking

cubic centimeters for the FVC and FEV_1, respectively, and 730 and 1,080 cubic centimeters for those with marked and severe dyspnea.

The observed FVC and FEV_1 decreased progressively as the degree of dyspnea increased in both the working and nonworking miners. The FVC and FEV_1 depression was greater, however, for the nonworking miners and for those whose FEV_1/FVC was less than 70 percent. Of all the comparative studies made between clinical findings and symptoms and ventilatory function, dyspnea was most closely correlated with alterations in the FVC and FEV_1.

Roentgenographic Category: International Labour Organization Pneumoconiosis Classification

A total of 2,418 working miners and 1,029 nonworking miners were compared to determine the relationships between pulmonary function and the alteration indicated in the chest roentgenograms. These relationships are shown for the working miners (Table 55 and Figure 38) and for the nonworking miners (Table 55 and Figure 39). The nonworking miners were older than the working miners in each of the roentgenographic categories. Height and weight were quite similar in the two groups. When compared with the predicted values, the FVC and FEV_1 for the nonworking miners and the FEV_1 for the working miners were depressed in all abnormal roentgenographic categories.

The prevalence of positive roentgenographic findings was higher for the nonworking miners than for the working miners. In neither group, however, was there a positive relationship between

TABLE 53—*Ventilatory function related to severity of bronchitis for all working and nonworking miners, those with FEV_1/FVC of 70 percent and above, and those with FEV_1/FVC less than 70 percent.*

Ventilatory function	Severity of bronchitis					
	None		Simple		Multiple	
	Working	Nonworking	Working	Nonworking	Working	Nonworking
Working and nonworking miners:						
Age, years	46	59	46	60	48	57
Height, centimeters	175	173	174	172	175	174
Weight, kilograms	77	75	73	71	78	73
FVC,[a] observed	4.23	3.55	4.00	3.16	4.10	3.28
FVC, predicted	4.35	3.98	4.31	3.92	4.30	4.08
FEV_1, observed	3.14	2.43	2.86	1.96	2.92	2.11
FEV_1, predicted	3.42	3.02	2.38	2.95	3.37	3.10
FEV_1/FVC	74	79	71	62	71	64
Miners with FEV_1/FVC 70 percent and above:						
Age, years	45	57	47	60	46	55
Height, centimeters	175	173	173	172	176	173
Weight, kilograms	79	77	74	77	79	75
FVC	4.29	3.69	4.20	3.22	4.32	3.49
FEV_1	3.40	2.88	3.29	2.50	3.41	2.69
FEV_1/FVC	79	78	78	78	79	77
Miners with FEV_1/FVC less than 70 percent:						
Age, years	48	59	46	50	51	58
Height, centimeters	175	174	176	172	175	175
Weight, kilograms	74	73	70	69	76	61
FVC	4.08	3.39	3.67	3.13	3.75	3.14
FEV_1	2.43	1.92	2.16	1.71	2.14	1.71
FEV_1/FVC	60	57	59	55	57	54

[a] Abbreviations used: see Table 43.

the depression of FVC or FEV_1 and the extent of the lung involvement as shown by abnormalities in the roentgenograms. The average body weights of both the working miners and the nonworking miners in the complicated roentgenographic category were several pounds less than those in the negative and suspect categories. The body weights of those in the simple category were intermediate. The lower body weights in the complicated roentgenographic category may indicate a poorer overall health status.

WORK CAPACITY

The working capacity test consisted of pedaling a Lanooy bicycle ergometer at 50 revolutions per minute against a resistance equivalent to 10, 25, 40, and 75 watts of external work. The resulting work energy expenditures were from two to five times the resting level. Edwards face masks fitted with low resistance Max Planck valves were connected by a baffle box to a paramagnetic oxygen analyzer and a bellows-type dry gas meter. Oxygen concentration in the expired air, respiration rate, ventilation volume, and pulse rate were monitored. Resting values were obtained with the subject seated on the ergometer before the start of the test. The 10-watt level served as a warmup period and lasted for 6 minutes, followed by increases to 25, 40, and 75 watts at 2 minute intervals. The subject pedaled continuously during the test, with expired air collected and measured for volume and oxygen concentration for the last minute of the rest and work periods. Work oxygen consumption, expressed in liters per minute and in milliliters per kilogram of body weight per minute, was then calculated from the oxygen concentration in the expired air for each work level. Pulse rates were measured for the last 30 seconds of each work period.

The number of individuals who completed the test at the lowest (10-watts) and highest work levels (75-watts for the men and 40-watts for the women) is tabulated in Table 56 according to the subject group. For various reasons, most of the

TABLE 54—*Ventilatory function related to degree of dyspnea for all working and nonworking miners, those with FEV_1/FVC of 70 percent and above, and those with FEV_1/FVC less than 70 percent.*

Ventilatory function	Degree of dyspnea					
	None or slight		Moderate		Marked and severe	
	Working	Nonworking	Working	Nonworking	Working	Nonworking
Working and nonworking miners:						
Age, years	44	57	47	58	51	55
Height, centimeters	175	172	175	174	174	173
Weight, kilograms	77	75	77	76	75	74
FVC,[a] observed	4.34	3.82	4.14	3.63	3.76	3.15
FVC, predicted	4.39	3.98	4.33	4.04	4.20	4.08
FEV_1, observed	3.28	2.83	3.02	2.52	2.46	1.95
FEV_1, predicted	3.48	3.02	3.40	3.10	3.25	3.12
FEV_1/FVC	76	74	73	69	65	62
Miners with FEV_1/FVC 70 percent and above:						
Age, years	44	56	46	57	48	58
Height, centimeters	175	171	175	173	174	173
Weight, kilograms	78	76	79	78	78	78
FVC	4.37	3.84	4.22	3.75	3.96	3.31
FEV_1	3.49	3.04	3.32	2.90	3.08	2.58
FEV_1/FVC	80	79	79	77	78	78
Miners with FEV_1/FVC less than 70 percent:						
Age, years	46	58	50	59	53	58
Height, centimeters	176	173	174	175	174	173
Weight, kilograms	75	70	74	74	73	72
FVC	4.22	3.77	3.98	3.49	3.58	3.07
FEV_1	2.56	2.26	2.35	2.06	1.92	1.61
FEV_1/FVC	61	60	59	59	54	52

[a] Abbreviations used: see Table 43.

nonworking miners of the pneumoconiosis prevalence survey group did not participate in the work capacity test. Failure to participate in the test resulted, in most instances, from the decision of the medical officer, although some subjects refused for personal reasons. Of the participants, about 15 percent of the men and 30 percent of the women were unable or unwilling to finish through their highest respective work levels. In most cases, failure to complete the test was the result of leg muscle fatigue or knee joint pain.

Pulse Rate

The data on pulse rates measured at rest and during the last 30 seconds of each work level are presented in Table 57 and Figure 40 for the working miners of the survey group and for the miners and nonminers at Richwood and Mullens.

No statistically significant differences were observed in the pulse rates at rest and during each of the four work levels between miners and nonminers as a function of age, either on the basis of measured heart rate or on the basis of the increment rise in heart rate resulting from each work level (work heart rate, less resting heart rate). Because increase in heart rate at any work level is indirectly proportional to the work capacity (physical fitness) of the individual,[7, 8] it must be concluded that the subject groups did not differ greatly in their overall physical condition and fitness.

The nonminers at Richwood, however, had a slightly higher pulse rate response on the work test than did the other groups. There is no explanation for this. If this resulted from a small change in methodology or in the ambient environment during the Richwood testing, the working miners at Richwood would be expected to show the same difference. The resting pulse rates of the Richwood miners and nonminers, however, were similar to those observed in the other groups, and the Richwood miners also responded to the work test about the same as did the working miners in the prevalence survey group and the working and nonminers at Mullens.

TABLE 55—*Ventilatory function related to roentgenographic category for all working and nonworking miners, for those with FEV_1/FVC of 70 percent and above, and those with FEV_1/FVC, less than 70 percent.*

Ventilatory function	Roentgenographic category							
	Negative		Suspect		Simple		Complicated	
	Working	Nonworking	Working	Nonworking	Working	Nonworking	Working	Nonworking
Working and nonworking miners:								
Age, years	45	57	50	59	51	59	53	60
Height, centimeters	175	173	174	174	174	173	175	173
Weight, kilograms	78	76	78	74	74	73	71	70
FVC [a], observed	4.25	3.53	4.05	3.48	4.05	3.50	4.17	3.37
FVC, predicted	4.37	4.00	4.24	3.96	4.20	3.98	4.20	3.96
FEV_1, observed	3.16	2.42	2.96	2.31	2.93	2.35	2.84	2.15
FEV_1, predicted	3.45	3.05	3.30	3.04	3.27	3.02	3.24	2.99
FEV_1/FVC	74	69	73	66	72	67	68	64
Miners with FEV_1/FVC 70 percent and above:								
Age, years	44	57	50	59	50	59	52	61
Height, centimeters	175	173	174	172	175	174	175	174
Weight, kilograms	79	78	78	73	75	77	74	68
FVC	4.32	3.66	4.09	3.62	4.12	3.75	4.24	3.58
FEV_1	3.43	2.86	3.26	2.77	3.23	2.93	3.23	2.78
FEV_1/FVC	79	78	80	76	78	78	76	78
Miners with FEV_1/FVC less than 70 percent:								
Age, years	47	58	52	59	54	59	54	60
Height, centimeters	175	174	175	175	172	173	175	173
Weight, kilograms	75	74	77	79	74	70	69	69
FVC	4.06	3.37	3.94	3.35	3.89	3.26	4.10	3.27
FEV_1	2.41	1.91	2.31	1.88	2.34	1.80	2.44	1.82
FEV_1/FVC	59	57	59	56	60	55	60	56

[a] Abbreviations used: see Table 43.

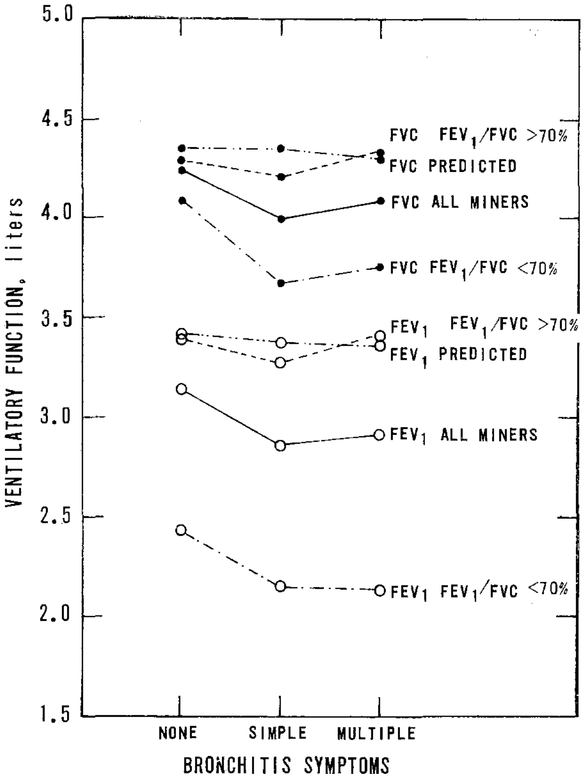

Figure 34.—Average forced vital capacity (FVC) and 1-second forced expiratory volume (FEV_1) for all working miners, working miners with FEV_1/FVC 70 percent and above, working miners with FEV_1/FVC less than 70 percent, and predicted values as related to the severity of symptoms of bronchitis

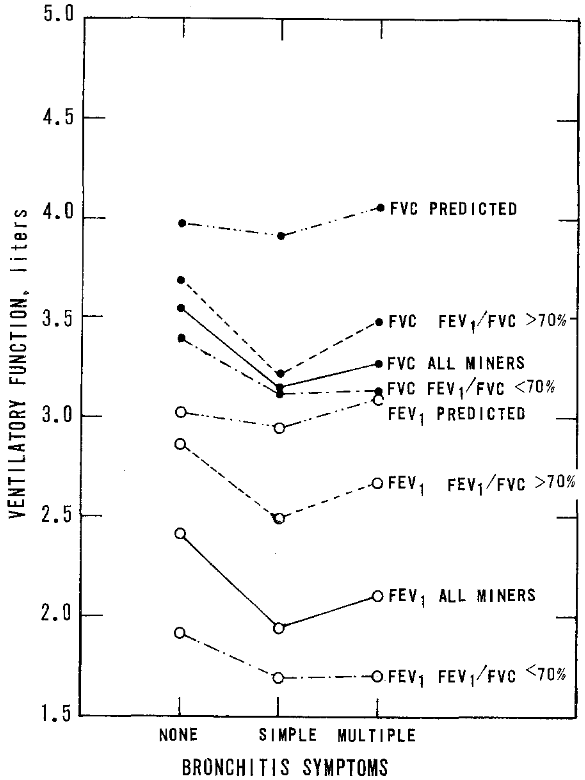

Figure 35.—Average forced vital capacity (FVC) and 1-second forced expiratory volume (FEV_1) for all nonworking miners, nonworking miners with FEV_1/FVC 70 percent and above, nonworking miners with FEV_1/FVC less than 70 percent, and predicted values related to the severity of symptoms of bronchitis

No systematic differences in pulse rates were observed between the two groups of wives tested (Table 57 and Figure 40). As with the men, age did not appear to handicap the women's capacity to handle work loads up through 40 watts. The pulse rates, at comparable work levels, however, were higher for the women than for the men. Each level of work required a higher proportion of the maximum aerobic work capacity in the women. The 40-watt level required 60 to 75 percent of the predicted maximum work capacity of the women whereas it was only 30 to 40 percent for the men. Even at approximately equal percentages of the predicted maximum work capacities (25 watts

TABLE 56—*Number of participants completing the 10- and 75-watt levels of work*

Group	Survey		Richwood		Mullens	
	Work level					
	10W	75W	10W	75W	10W	75W
Working miners	1,806	1,666	129	108	122	108
Nonminers			106	88	115	94
Females			169	105 [a]	92	63 [a]

[a] For 40-watts.

TABLE 57—*Mean pulse rates (beats per minute) during the graded work test for all groups surveyed*

Group	Work level, watts	Miners			Nonminers			Wives		
		<40	40–50	>50	<40	Age group 40–50	>50	<40	40–50	>50
Survey working miners	Rest	91 (18)[a]	89 (16)	86 (15)	...	...	...	...	...	...
	10	99 (17)	97 (16)	95 (14)	...	...	...	...	...	...
	25	105 (18)	103 (15)	100 (15)	...	...	...	...	...	...
	40	111 (18)	109 (16)	106 (15)	...	...	...	...	...	...
	75	126 (19)	123 (17)	121 (16)	...	...	...	...	...	...
Richwood	Rest	86 (12)	85 (15)	80 (9)	90 (13)	89 (14)	90 (15)	95 (14)	91 (15)	88 (12)
	10	99 (13)	96 (14)	92 (10)	103 (14)	103 (15)	99 (13)	114 (15)	113 (18)	111 (15)
	25	105 (13)	103 (13)	100 (12)	108 (13)	110 (15)	106 (13)	122 (14)	121 (18)	123 (14)
	40	111 (12)	111 (12)	105 (11)	115 (13)	118 (17)	116 (15)	132 (14)	131 (17)	137 (16)
	75	125 (13)	123 (11)	120 (10)	130 (15)	133 (14)	129 (17)	...	...	...
Mullens	Rest	88 (14)	88 (11)	86 (12)	92 (17)	88 (12)	90 (13)	99 (15)	97 (13)	90 (10)
	10	96 (13)	94 (11)	93 (13)	103 (17)	96 (12)	100 (16)	120 (17)	114 (13)	107 (9)
	25	102 (13)	101 (11)	100 (12)	109 (17)	102 (11)	108 (16)	130 (18)	122 (13)	115 (17)
	40	107 (12)	105 (8)	106 (13)	116 (18)	109 (12)	109 (15)	142 (20)	132 (13)	136[b]
	75	125 (12)	123 (10)	125 (12)	129 (14)	123 (10)	125 (15)	...	...	...

[a] Standard deviation.
[b] No standard deviation calculated for less than 10 subjects per grouping.

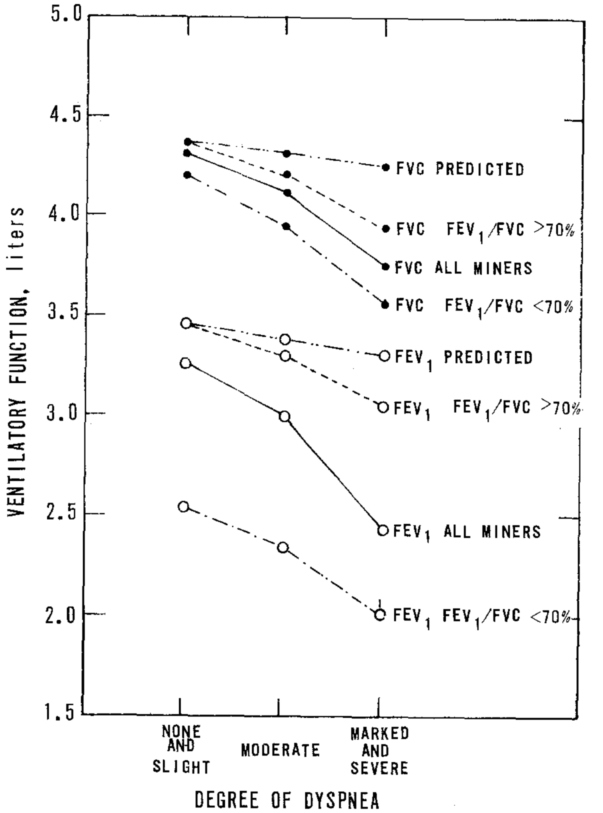

Figure 36.—Average forced vital capacity (FEV) and 1-second forced expiratory volume (FEV_1) for all working miners, working miners with FEV_1/FVC 70 percent and above, nonworking miners with FEV_1/FVC less than 70 percent, and predicted values related to degree of dyspnea

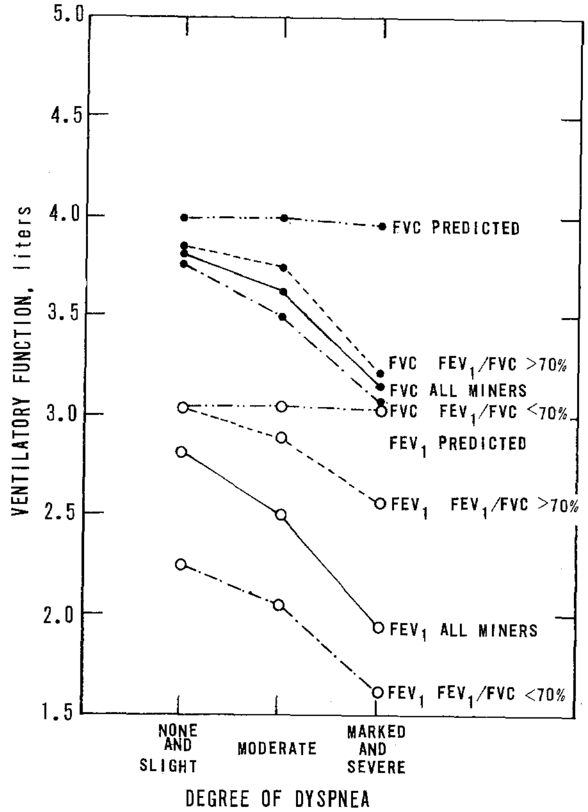

Figure 37.—Average forced vital capacity (FVC) and 1-second forced expiratory volume (FEV_1) for all nonworking miners, nonworking miners with FEV_1/FVC 70 percent and above, nonworking miners with FEV_1/FVC less than 70 percent, and predicted values related to degree of dyspnea

for females as against 40 watts for males), however, the women's pulse rates were higher: about 120 beats per minute compared with 110 beats per minute for males. The women's expenditure at all work levels was proportionally higher, indicating that the relative level of physical fitness was lower in women than in men. In general, the level of physical fitness reflects daily work energy expenditure.

Maximum Aerobic Work Capacity

Maximum capacity to accomplish physical work can be measured directly by tests requiring the individual to work at levels of severity that result in exhaustion in a few minutes, but such tests are not practical for routine studies. Maximum aerobic work capacity can be predicted, however, from pulse rate response to work levels that do not exhaust the subject.[9, 10] Predicted maximum aerobic work capacities were calculated from the pulse rate responses to 75-watt work levels for men and 40-watt work levels for women, and the predicted data (oxygen consumption measured in liters per minute) are presented in Table 58.

It might have been expected that men over 50 years of age would be less physically fit than younger men, and the work loads for the work test were chosen so that the highest energy expenditure would not exceed 50 percent of the average individual's maximum aerobic work capacity. Age does not necessarily affect performance at moderate work levels, but maximum aerobic work capacity does decrease as a function of age. Several consistent differences in predicted work capacities were observed. In all the groups,

TABLE 58—*Mean predicted maximal oxygen consumption (liters per minute) for all groups surveyed*

Groups	Age group		
	<40	40–50	>50
Survey miners	2.94 (0.81) [a]	2.84 (0.84)	2.70 (0.82)
Richwood miners	3.23 (0.62)	2.92 (0.68)	2.81 (0.53)
Richwood nonminers	3.13 (0.70)	2.77 (0.55)	2.71 (0.64)
Mullens miners	3.74 (0.70)	3.45 (0.88)	3.47 (1.16)
Mullens nonminers	3.56 (1.05)	3.25 (0.67)	3.16 (0.82)
Richwood wives	2.02 (0.53)	1.95 (0.66)	1.87 [b]
Mullens wives	2.00 (0.53)	2.14 (0.69)	....

[a] Standard deviation.
[b] No standard deviation calculated for less than 10 subjects per grouping.

the predicted values decreased progressively with age except for the Mullens miners in the 40 to 50 and over 50 age groups and the Mullens wives under 30 and between 40 and 50 years of age.

The miners in Mullens had the highest predicted maximum aerobic work capacity of all groups, and their capacity exceeded that of the Mullens nonminers. The Richwood miners had a lower capacity than either of the two Mullens groups but higher than the Richwood nonminers.

The miners comprising the pneumoconiosis survey group had the lowest predicted maximum aerobic capacity of all the male subject groups. There were no observed differences, either in body size or general physical conditions, that could account for these differences. The wives in Mullens and Richwood did not differ in predicted maximum aerobic work capacity.

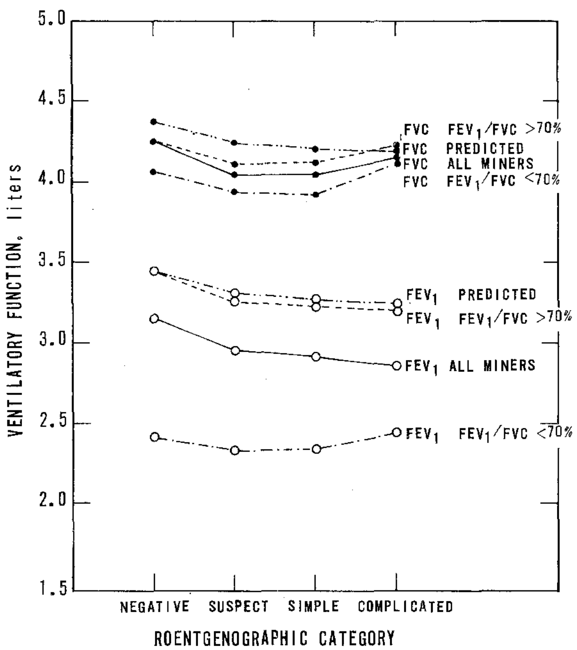

Figure 38.—Average forced vital capacity (FVC) and 1-second forced expiratory volume (FEV_1) for all working miners, working miners with FEV_1/FVC 70 percent and above, working miners with FEV_1/FVC less than 70 percent, and predicted values related to the roentgenographic category

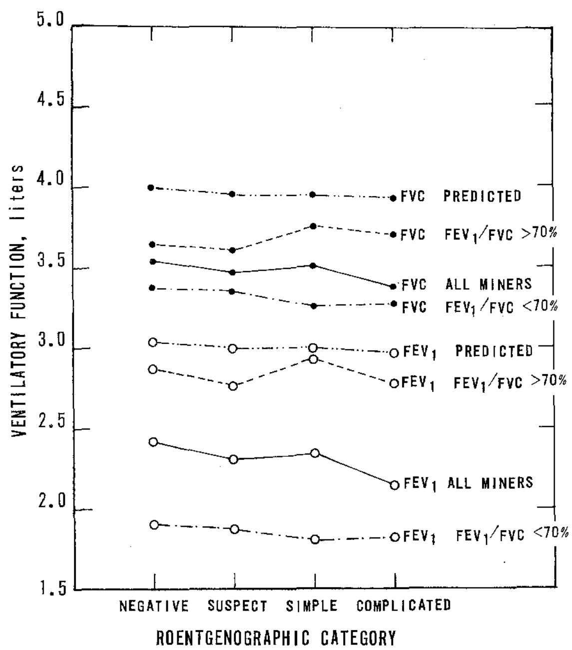

Figure 39.—Average forced vital capacity (FVC) and 1-second forced expiratory volume (FEV_1) for all nonworking miners, nonworking miners with FEV_1/FVC 70 percent and above, nonworking miners with FEV_1/FVC less than 70 percent, and predicted values related to the roentgenographic category

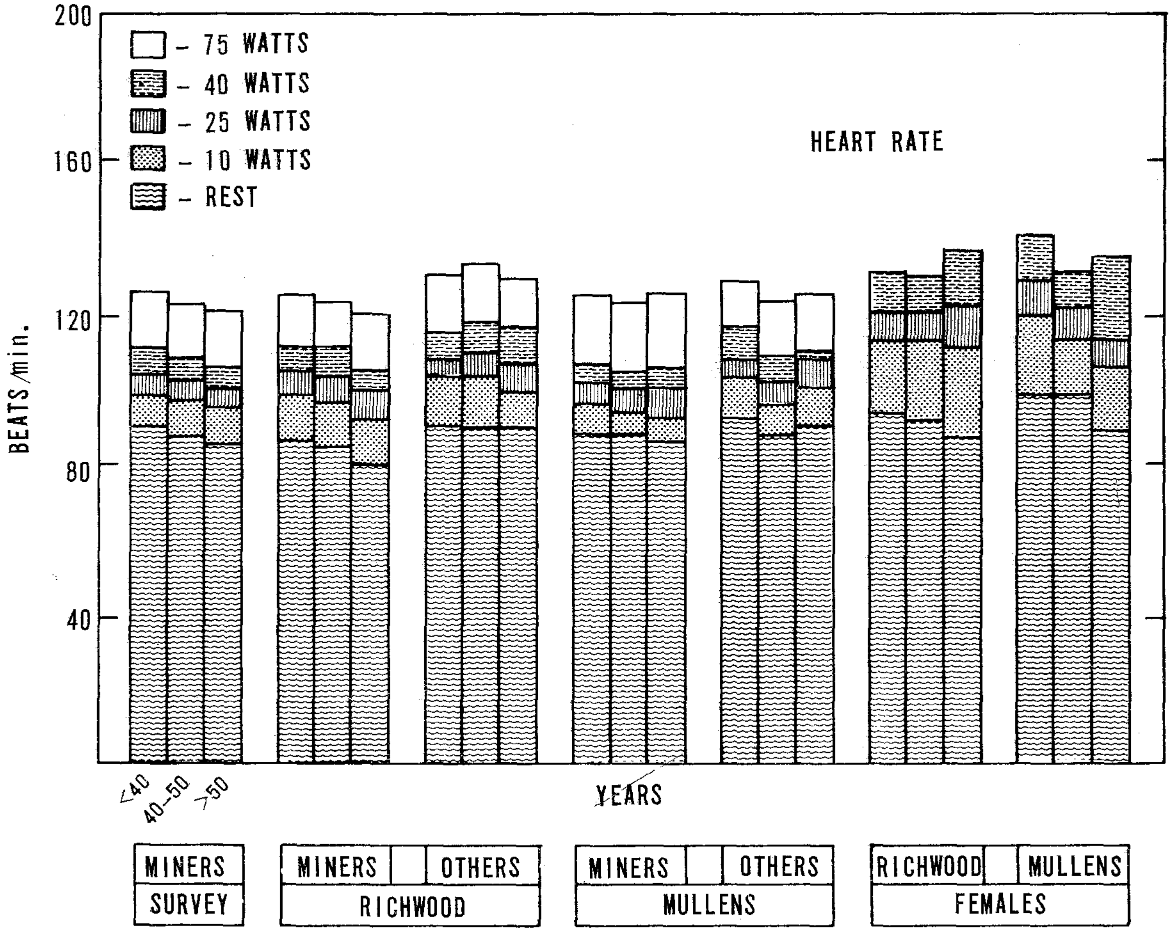

Figure 40.—Pulse rates (beats per minute) during graded work test for all groups surveyed

Except for the Mullens subjects, the groups all had low normal predicted maximum aerobic work capacity values. These low capacities might be due to poor health and nutrition or the population studied may not be as physically active as other groups (including the Mullens groups). The work test provided no data on these points, but predicted maximum work capacity was lower than expected.

Oxygen Consumption

The oxygen consumed during any level of physical work is a measurement of the amount of fuel used by the individual to do the work. In general, oxygen consumption increases directly with an increase in the severity of the work. Oxygen consumed, expressed in liters per unit time, is the total energy cost to the individual. Since the muscle mass (which uses most of the oxygen during work) differs greatly between individuals, however, total oxygen consumption may not reflect the true relative physiological strain to individuals doing the same work. For this reason, oxygen consumption, expressed in cubic centimeters per kilogram body weight per minute, is measured to obtain more meaningful data.

Oxygen consumption at rest and during the four levels of work on the bicycle ergometer for the miners and nonminers is given in liters per minute (Table 59 and Figure 41) and in cubic centimeters per kilogram body weight per minute (Table 60 and Figure 42). As expected, the oxygen consumption increased progressively and consistently with increase in work level. The data indicate that individual energy cost varied but that all groups were readily capable of handling the work levels required in the test. Oxygen consumption was lowest in the pneumoconiosis survey miner groups, intermediate in the Richwood miners and nonminers, and highest in the Mullens miners and nonminers. At most work levels, both Richwood and Mullens nonminers consumed less oxygen than did the miners. The reasons for this are not apparent; however, roentgenographic evidence of pneumoconiosis was highest in the Mullens subjects.

Data are given for the oxygen consumption (Table 59) and the oxygen consumption corrected for body weight (Table 60), for the Mullens and Richwood wives. As with the men, no consistent age trend was observed. There was, however, a difference between the two groups of women: the Mullens women consumed more oxygen at every work level (including rest) than did the Richwood women. This was true for total oxygen consumption and for oxygen consumption per unit of body weight. This higher oxygen cost was not accompanied by higher pulse rate; this would happen if the work were physiologically harder for the Mullens wives. It is possible that the Mullens women were, as a group, less relaxed during the test. The Mullens wives also had a higher oxygen consumption at rest that might account for the correspondingly high oxygen consumption at work. Their pulse rates were also higher at rest.

Ventilation Volumes

The amount of air moved in and out of the lungs during a measured physical activity is useful in assessing the overall physical fitness of

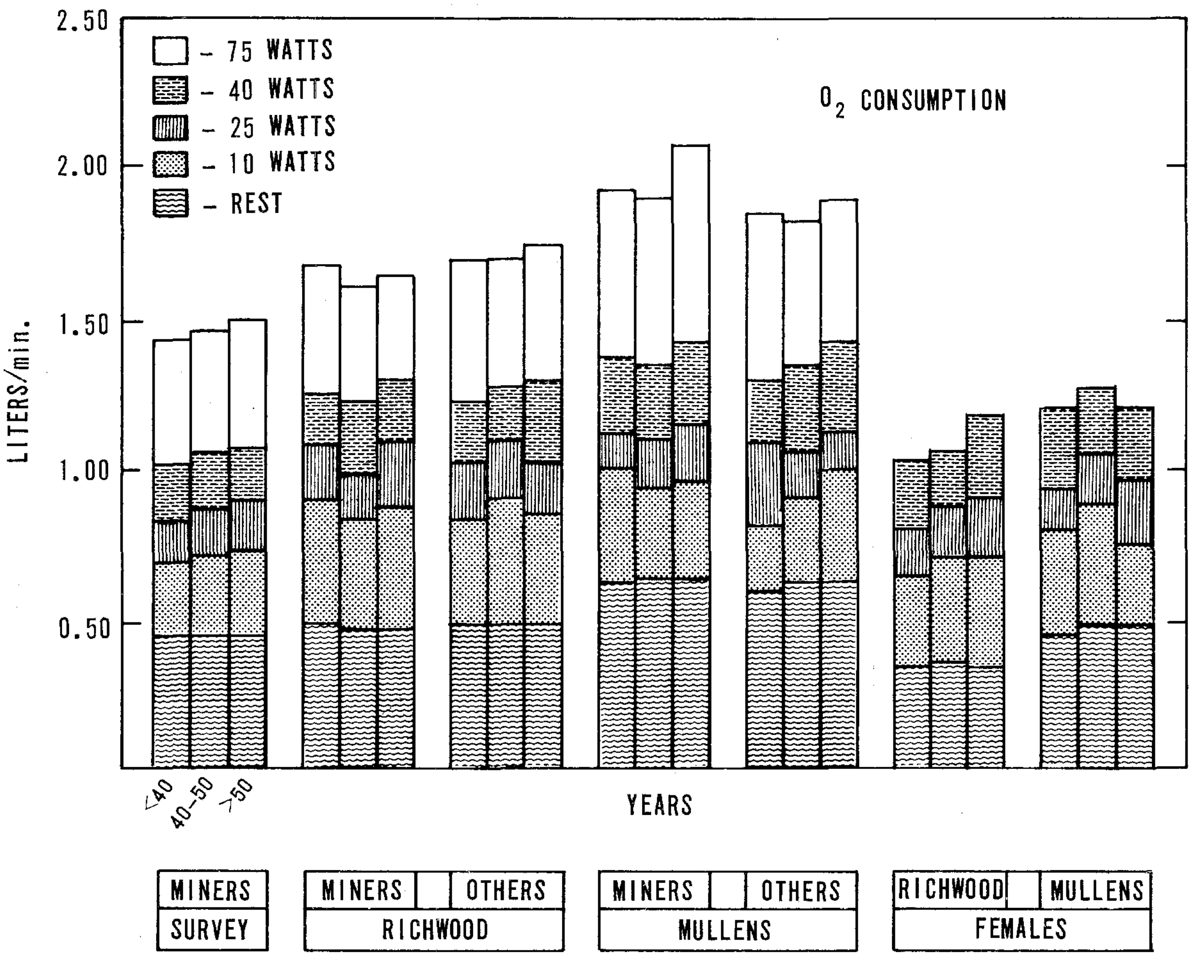

Figure 41.—Oxygen consumption (liters per minute) during graded work test for groups surveyed

TABLE 59—*Mean oxygen consumption (liters per minute) during graded work test for all groups surveyed.*

Group	Work level, watts	Miners			Nonminers			Wives		
		Age group								
		<40	40–50	>50	<40	40–50	>50	<40	40–50	>50
Survey Working miners	Rest	0.44 (0.11)[a]	0.44 (0.12)	0.44 (0.13)	...	...	...	...	...	...
	10	0.68 (0.14)	0.70 (0.16)	0.72 (0.18)	...	...	...	...	...	...
	25	0.82 (0.15)	0.85 (0.19)	0.89 (0.42)	...	...	...	...	...	...
	40	1.01 (0.17)	1.04 (0.19)	1.06 (0.21)	...	...	...	...	...	...
	75	1.42 (0.21)	1.45 (0.25)	1.49 (0.27)	...	...	...	...	...	...
Richwood	Rest	0.49 (0.12)	0.47 (0.12)	0.47 (0.10)	0.48 (0.13)	0.47 (0.09)	0.46 (0.10)	0.34 (0.09)	0.35 (0.10)	0.33 (0.10)
	10	0.90 (0.19)	0.84 (0.17)	0.87 (0.20)	0.84 (0.15)	0.91 (0.18)	0.85 (0.17)	0.64 (0.17)	0.70 (0.15)	0.72 (0.16)
	25	1.08 (0.14)	0.98 (0.20)	1.09 (0.19)	1.02 (0.19)	1.09 (0.19)	1.03 (0.20)	0.80 (0.17)	0.87 (0.18)	0.90 (0.21)
	40	1.25 (0.15)	1.22 (0.22)	1.29 (0.19)	1.22 (0.19)	1.27 (0.21)	1.29 (0.16)	1.02 (0.21)	1.06 (0.22)	1.17 (0.23)
	75	1.68 (0.17)	1.61 (0.27)	1.64 (0.25)	1.70 (0.20)	1.70 (0.18)	1.75 (0.20)	...	...	...
Mullens	Rest	0.62 (0.17)	0.64 (0.12)	0.63 (0.15)	0.60 (0.14)	0.62 (0.14)	0.61 (0.16)	0.45 (0.12)	0.48 (0.14)	0.49 (0.16)
	10	0.99 (0.21)	0.93 (0.20)	0.96 (0.20)	0.82 (0.21)	0.91 (0.15)	0.98 (0.23)	0.79 (0.18)	0.87 (0.11)	0.74 (0.15)
	25	1.12 (0.22)	1.11 (0.22)	1.15 (0.19)	1.09 (0.22)	1.06 (0.19)	1.12 (0.22)	0.93 (0.16)	1.04 (0.12)	0.95 (0.12)
	40	1.37 (0.19)	1.34 (0.17)	1.42 (0.17)	1.29 (0.20)	1.34 (0.18)	1.42 (0.20)	1.20 (0.23)	1.27 (0.15)	1.20[b]
	75	1.93 (0.22)	1.90 (0.22)	2.08 (0.20)	1.85 (0.25)	1.82 (0.21)	1.89 (0.24)	...	...	...

[a] Standard deviation.
[b] No standard deviation calculated for less than 10 subjects per grouping.

TABLE 60—*Oxygen consumption (cubic centimeters per kilogram of body weight per minute) during graded work test for all groups surveyed*

Group	Work level, watts	Miners			Nonminers			Wives		
		Age group								
		<40	40–50	>50	<40	40–50	>50	<40	40–50	>50
Survey working miners.	Rest	5.9 (1.5)[a]	5.9 (3.4)	5.8 (1.6)	...	...	...	...	...	...
	10	9.0 (1.9)	9.0 (1.9)	9.4 (2.2)	...	...	...	...	...	...
	25	10.9 (2.1)	11.0 (2.3)	11.6 (2.6)	...	...	...	...	...	...
	40	13.5 (2.4)	13.5 (2.5)	14.1 (3.0)	...	...	...	...	...	...
	75	18.9 (3.6)	18.8 (3.6)	19.6 (4.0)	...	...	...	...	...	...
Richwood	Rest	6.4 (1.2)	6.5 (1.5)	6.4 (1.5)	6.2 (1.5)	6.5 (1.2)	6.3 (1.5)	5.5 (1.5)	5.4 (1.3)	5.0 (1.5)
	10	11.7 (2.0)	11.8 (2.3)	11.7 (3.2)	11.1 (2.0)	12.6 (2.3)	11.5 (2.3)	10.4 (2.8)	10.1 (3.0)	10.8 (3.0)
	25	14.3 (2.2)	13.8 (2.9)	14.6 (3.2)	13.3 (2.3)	14.9 (2.8)	13.9 (2.6)	13.2 (3.0)	13.6 (2.9)	14.1 (3.6)
	40	16.7 (2.7)	17.2 (2.9)	17.0 (3.4)	16.1 (2.7)	17.6 (3.1)	17.6 (2.6)	16.9 (4.0)	16.6 (4.6)	17.2 (4.5)
	75	22.4 (3.5)	22.9 (3.9)	22.6 (3.6)	21.9 (3.7)	23.7 (3.7)	23.0 (3.4)	...	...	...
Mullens	Rest	7.8 (2.3)	8.4 (1.7)	9.1 (2.1)	7.3 (1.7)	7.9 (1.8)	7.6 (2.1)	7.6 (1.9)	7.4 (2.2)	7.4 (1.9)
	10	12.3 (2.3)	12.2 (2.3)	13.8 (3.1)	10.7 (2.1)	11.5 (2.0)	12.1 (2.8)	13.4 (2.8)	13.3 (1.9)	11.3 (1.4)
	25	14.4 (2.5)	14.6 (2.7)	16.8 (3.4)	13.2 (2.1)	13.6 (2.4)	14.1 (2.7)	15.9 (3.0)	16.7 (2.0)	14.6 (0.6)
	40	17.3 (2.6)	17.4 (2.5)	20.8 (3.2)	16.0 (2.5)	17.1 (2.7)	18.2 (3.1)	19.9 (3.2)	20.4 (3.0)	20.7[b]
	75	24.4 (3.6)	25.1 (3.7)	30.8 (3.9)	22.7 (4.2)	23.5 (4.0)	23.3 (3.7)	...	...	...

[a] Standard deviation.
[b] No standard deviation calculated for less than 10 subjects per grouping.

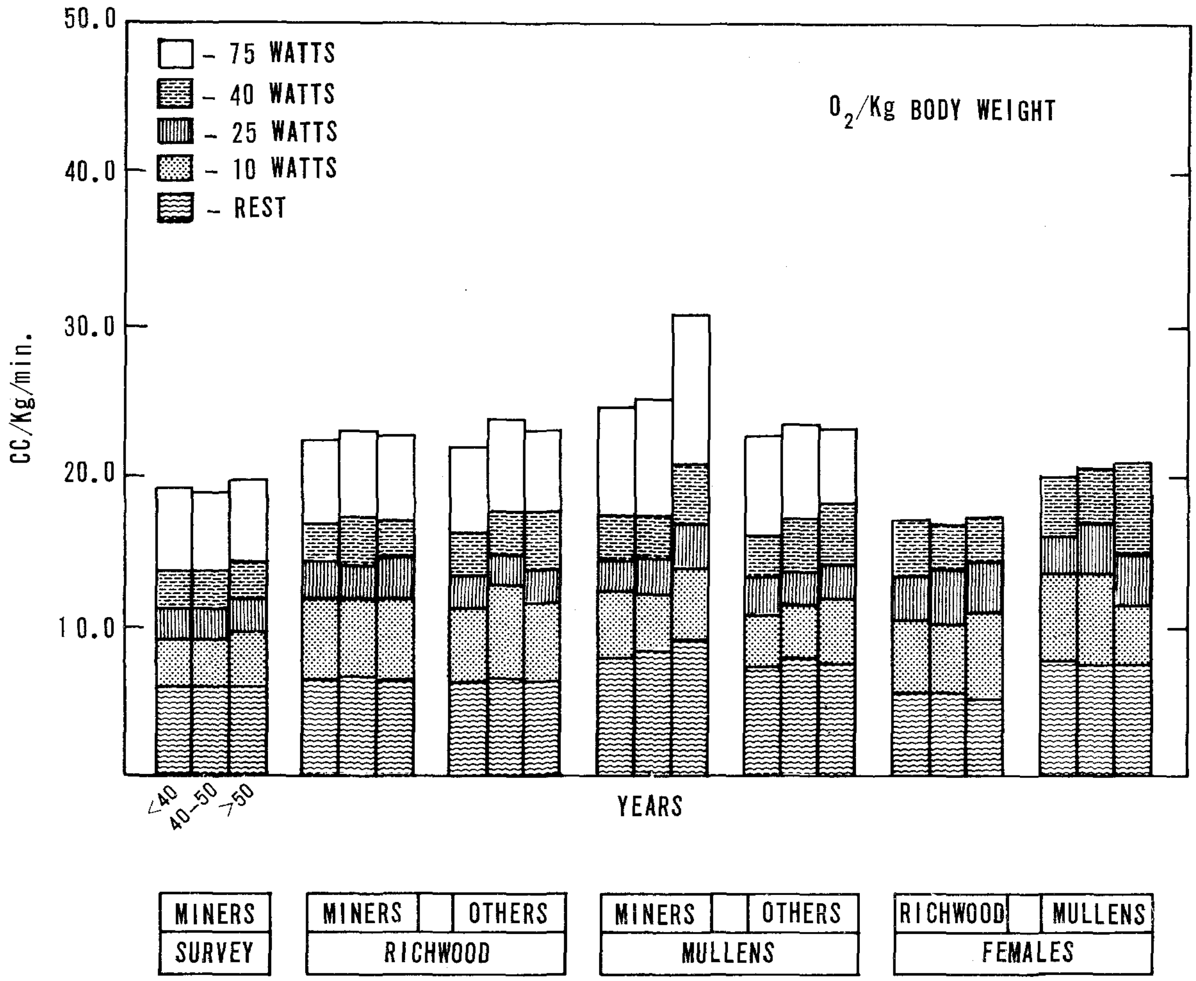

Figure 42.—Oxygen consumption (cubic centimeters per kilogram of body weight per minute) for all groups surveyed

various population groups. At moderate work levels, individuals who are less fit tend to hyperventilate; this should occur only as work approaches maximum work capacity.

Ventilation volumes at rest and during the work are given in Table 61 and Figure 43 for miners and nonminers and for their wives. As expected, pulmonary ventilation was about the same for all age and subject groups during rest when the demands on the cardio-respiratory system were minimal. Ventilatory volume increased with age for the three groups of miners (Survey, Richwood, and Mullens) and the two groups of nonminers (Richwood and Mullens) at all levels of physical work. Increased ventilation with increased work is the normal physiological response and was within acceptable range of values for all groups. No striking or consistent differences in ventilation were observed for miners or nonminers at any work level or age group. Thus, in no group was the capacity of the respiratory system to move air or exchange gases seriously inadequate for the work levels used in the test.

The Richwood and Mullens wives showed no ventilatory differences at any work level or age group (Table 61 and Figure 43), and the usual increase in ventilation with increase in work level occurred. Resting ventilation volume was smaller for the females, as expected. At the 10, 25, and 40-watt work levels, however, total ventilation was about equal for both male and female groups. This, in effect, represented a relative hyperventi-

TABLE 61—*Ventilation volumes (liters per minute) during the graded work test for all groups surveyed.*

Group	Work level, watts	Miners			Nonminers			Wives		
		Age group								
		<40	40–50	>50	<40	40–50	>50	<40	40–50	>50
Survey working miners.	Rest	11.3 (2.7)[a]	11.5 (2.9)	11.7 (3.0)	...	...	...	...	...	...
	10	17.1 (3.6)	17.7 (3.8)	18.8 (5.2)	...	...	...	...	...	...
	25	19.6 (3.7)	20.6 (4.3)	21.5 (4.4)	...	...	...	...	...	...
	40	22.7 (4.0)	23.8 (4.2)	24.8 (4.3)	...	...	...	...	...	...
	75	29.3 (5.1)	30.8 (5.5)	32.5 (5.8)	...	...	...	...	...	...
Richwood	Rest	11.3 (2.4)	11.9 (2.9)	11.7 (2.7)	11.1 (2.7)	11.6 (2.2)	12.2 (2.3)	9.2 (2.1)	9.3 (2.4)	9.1 (3.0)
	10	19.0 (2.8)	19.4 (3.9)	21.1 (4.6)	19.1 (3.4)	21.2 (3.8)	21.1 (3.0)	16.9 (3.9)	17.8 (4.0)	17.8 (4.0)
	25	22.1 (2.7)	21.5 (4.4)	24.7 (4.7)	21.5 (4.0)	23.5 (3.8)	23.7 4.1)	19.8 (4.1)	20.9 (4.1)	21.8 (4.1)
	40	24.7 (3.5)	25.5 (4.9)	28.5 (4.7)	24.6 (3.9)	26.8 (4.3)	28.4 (3.6)	23.5 (4.2)	24.0 (4.2)	25.4 (4.3)
	75	30.8 (3.6)	31.8 (4.9)	34.7 (5.8)	31.8 (4.7)	34.1 (4.9)	38.2 (6.6)	...	...	...
Mullens	Rest	11.5 (3.2)	11.8 (2.5)	12.4 (2.9)	11.2 (2.7)	11.8 (2.7)	12.4 (3.2)	8.9 (2.3)	9.2 (2.7)	9.7 (2.6)
	10	17.4 (3.5)	17.1 (3.8)	18.3 (4.3)	16.2 (3.7)	17.2 (3.1)	19.1 (4.8)	15.3 (3.6)	16.5 (2.3)	15.1 (2.6)
	25	18.8 (3.8)	19.5 (4.4)	21.4 (4.0)	19.1 (3.7)	19.5 (3.9)	21.1 (4.5)	17.6 (3.4)	19.2 (2.3)	18.7 (2.8)
	40	22.3 (3.2)	22.8 (3.6)	25.0 (3.7)	21.2 (3.4)	23.5 (3.7)	25.6 (4.8)	21.7 (3.9)	23.5 (3.6)	24.4[b]
	75	29.2 (3.6)	29.8 (4.2)	35.6 (6.1)	29.1 (3.8)	29.3 (5.2)	30.5 (4.3)	...	...	...

[a] Standard deviation.
[b] No standard deviation calculated for less than 10 subjects per grouping.

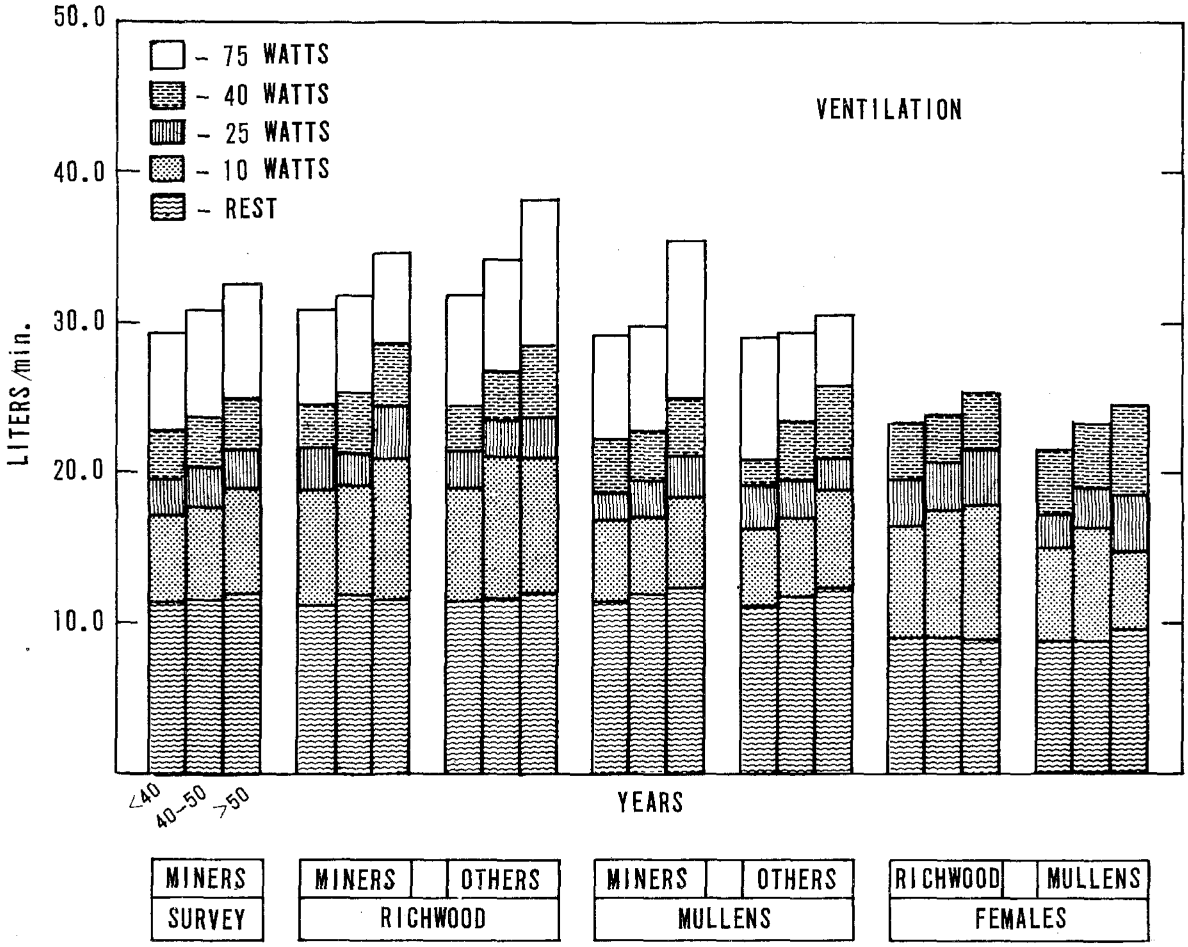

Figure 43.—Ventilation volumes (liters per minute) during the graded work test for all groups surveyed

lation for the female groups; decreased oxygen removal ratio is usually seen in individuals who are less fit physically. The hyperventilation in the females would indicate that each work level was harder for the women than for the men, and higher observed work pulse rates would support this conclusion. There was no evidence, however, that the work capacity of the females in this study was limited because of respiratory inadequacies.

Age and Weight Effects

Data obtained during the pneumoconiosis prevalence survey provided the opportunity to explore the problem of whether age and body weight affect physiological responses to physical work at various levels of intensity. The first 765 working miners who completed the entire work test were utilized for this analysis. For purposes of determining the effects of age, the subjects were divided into three groups: under 40 years of age, 40 to 50 years of age, and over 50 years of age. For determining body weight effects, the subjects were divided into four body weight groups: below 65 kilograms (143.3 pounds), 65 to 77 kilograms (143.3 to 172.0 pounds), 78 to 89 kilograms (172.0 to 198.4 pounds), and 90 and over kilograms (198.4 pounds). The number of individuals comprising each age and weight group are given in Table 62.

The oxygen consumption increases (over resting levels) as related to age, body weight, and work load are presented in Table 63. For work loads of 10, 25, and 40 watts, there is a statis-

TABLE 62—*Number of working miners in each body weight and age group*

Body weight, kilograms	Age group			
	<40	40–50	>50	Total
<65	37	43	30	110
65 through 77	134	143	73	350
78 through 89	81	85	37	203
>90	33	49	20	102
Total	285	320	160	765

tically significant (P<0.005), consistent, and progressively higher oxygen consumption with increasing body weight. At the 25-watt work level, the increasing trend for higher oxygen consumption in the heavier men is not as well defined or regular but still persists (P<0.01). This is consistent with other observations (Tables 60, 65, and 66) that total oxygen consumption is higher for heavy men compared with lighter men working at several energy expenditure levels. A higher oxygen consumption has been observed in obese men and women than in slender individuals working on a bicycle ergometer. A linear relationship between body weight and oxygen consumption during work against gravity is a well accepted concept.[11, 12] Several authors, however, have reported that for nonobese individuals working on a bicycle ergometer there is no relationship between body weight and the energy cost of the work.[11]

No statistically consistent relationship was observed between oxygen consumption and age at any level of work capacity test. Ability to work at levels that do not exceed 40 to 50 percent of the maximum oxygen utilization capacity does not seem to be seriously reduced in otherwise healthy men up to 60 to 65 years of age.

The heart rate increase during work reflects the severity of the job, the physiological strain resulting from the work, and the physical work capacity of the individual. The relationship between work heart rates and body weight, age, and level of work are shown in Table 64. At none of the work levels is there an increase in work pulse rate consistent with increase in age. At the 40- and 75-watt work levels, however, a trend of decreasing pulse rates with increasing body weights was observed. When oxygen consumption is corrected

TABLE 63—*Mean increase in work oxygen consumption (cubic centimeters per minute) related to age, body weight, and work levels for working miners in study group*

Body weight, kilograms	Work level, watts	Age group		
		<40	40–50	>50
<65	10	187	171	191
	25	355	304	376
	40	532	540	563
	75	1,044	959	1,060
65 through 77	10	215	193	229
	25	361	351	375
	40	554	566	577
	75	989	1,001	1,043
78 through 89	10	229	248	304
	25	370	401	423
	40	586	578	627
	75	1,058	1,029	1,125
>90	10	268	265	316
	25	422	420	464
	40	654	628	627
	75	1,036	1,057	1,097

for weight, the same trends are observed: no relationship to age and an inverse relationship to body weight. If the work had taxed the physiological capabilities of the older men to a greater degree than it did the younger men, higher oxygen consumptions and work pulse rates would have been apparent. These data strengthen our theory that submaximum aerobic work capacity does not necessarily deteriorate as a function of age.[11, 13] It should be emphasized, however, that the men who participated in this study were in reasonably good health, were physically capable of doing a full day's work on the job, and were able to complete the work test. If the work intensity were heavier, the duration of exercise longer, or the men in ill health or poor physical condition, it would be expected that the older men would eventually show evidence of increased physiological strain.

The predicted maximum oxygen utilization was calculated by the extrapolation method[9, 10] and is based on the pulse rate and oxygen consumption responses to a series of progressively harder work loads. The calculated data are presented in Table 65. The predicted maximum oxygen utilization capacity was found to increase with increasing body weight, and decrease with increasing age. Therefore, although the ability to perform mod-

TABLE 64—*Mean increase in work heart rate (beats per minute) related to body weight, age, and work level for working miners in study group.*

Body weight, kilograms	Work level, watts	Age group <40	40–50	>50
<65...............	10	8	9	9
	25	15	16	16
	40	23	23	23
	75	43	45	45
65 through 77.......	10	8	8	6
	25	14	13	12
	40	21	20	18
	75	38	37	35
78 through 89.......	10	7	8	9
	25	12	14	13
	40	17	20	19
	75	31	34	35
>90...............	10	8	6	8
	25	16	12	14
	40	20	17	18
	75	35	30	32

erately hard physical work may not be age-dependent, apparently the ability to accomplish maximum intensity work does decrease with increasing age.

The relative physiological strain on the individual at each work level can be determined from the data on work oxygen consumption and calculated maximum oxygen utilization capacity. Table 66 presents the percentage of the predicted maximum oxygen utilization capacity that is required for each of the four levels of work as related to body weight and age. For all work levels, the men over 50 years of age expended a higher percentage of their predicted maximum capacity than did the younger men. At the lower levels of aerobic work, the older workers would not be handicapped, but, with increasing work intensities, they would reach maximum work output levels sooner than the younger men.

TABLE 65—*Mean predicted maximum oxygen capacity (liters per minute) related to age and body weight for working miners in substudy group.*

Body weight, kilograms	Age group <40	40–50	>50
<65.................	2.201	2.090	1.965
65 through 77.........	2.612	2.494	2.418
78 through 89.........	2.960	2.773	2.513
>90.................	3.353	3.070	2.897

TABLE 66—*Increase in work oxygen consumption as percent of predicted maximum oxygen capacity related to age, body weight, and work level for working miners in substudy group.*

Body weight, kilograms	Work levels, watts	Age group <40	40–50	>50
<65...............	10	8	8	10
	25	16	15	19
	40	24	26	29
	75	47	46	54
(Mean by weight, 25.2)				
65 through 75.......	10	8	8	9
	25	14	14	16
	40	21	23	24
	75	38	40	43
(Mean by weight, 21.5)				
78 through 89.......	10	8	9	12
	25	13	14	17
	40	20	21	25
	75	35	37	45
(Mean by weight, 21.3)				
>90...............	10	8	9	11
	25	13	14	16
	40	20	20	22
	75	31	34	38
(Mean by weight, 19.7)				
Mean by age.......	10	8.0	8.5	10.5
	25	14.0	14.3	17.0
	40	21.3	22.5	25.0
	75	37.8	39.3	45.0

At 25-, 40-, and 75-watt work levels, the lighter men expended a higher percentage of their predicted maximum oxygen capacity than did the heavier men and their work pulse rates were also higher. Although the work oxygen consumption was linearly related to body weight, the predicted maximum oxygen capacity increased relatively more with weight than did the work oxygen consumption. This greater maximum capacity in the heavier men may be due to greater muscle mass.[11]

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SECTION VI

Summary and Conclusions

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Summary and Conclusions

SUMMARY OF FINDINGS

Although there were no large-scale epidemiologic studies among bituminous coal miners in the United States before a study of the Pennsylvania Department of Health conducted from 1959 to 1961, several clinical studies had indicated that coal miners did suffer disease, as evidenced by changes in chest roentgenograms, respiratory symptoms, and alterations in pulmonary function.

The survey reported in this document, which was conducted by the U.S. Public Health Service from 1963 to 1965, was undertaken to determine the prevalence of coal miners' pneumoconiosis in two population groups: (1) working and nonworking miners in the Appalachian bituminous coal fields, and (2) working miners and their wives and nonminers and their wives in two West Virginia communities.

In the first population group, a statistical sample of 2,549 working and 1,191 nonworking Appalachian coal miners was examined. Questionnaires were used to obtain medical, occupational, and smoking histories. Chest roentgenograms, ventilatory pulmonary function measurements, and measurements of work capacity also were made. About 10 percent of the working miners and 24 percent of the nonworking miners reported persistent productive cough, which correlated with the number of years that the miners worked underground. Dyspnea appeared to be associated more with age than with underground mining experience and occurred several times as frequently among nonworking as among working miners. Cigarette smoking habits were positively associated with persistent productive cough and dyspnea. Roentgenographic evidence of pneumoconiosis that was positively associated with both age and number of years of underground experience was present in almost 10 percent of the working and 18 percent of the nonworking miners examined. Among the working miners, 6.8 percent showed evidence of simple pneumoconiosis and 3.0 percent showed evidence of complicated disease; the percentages for the nonworking miners were 9.2 and 9.0, respectively. Roentgenographic evidence of pneumoconiosis was present in 11.2 percent of the working underground miners and 2.5 percent of the surface workers. Miners who worked at the coal face showed more roentgenographic change than other underground coal miners, and of these "faceworkers", cutting machine operators showed the highest prevalence of pneumoconiosis (22.3 percent of working and 33.3 percent of nonworking miners). There appeared to be a linear correlation between the appearance of roentgenographic change and underground experience in miners with more than 15 years such experience. Little correlation was noted between the roentgenographic evidence of pneumoconiosis and respiratory symptoms and none was noted between roentgenographic changes and smoking habits.

Pulmonary ventilatory function, both the observed 1-second forced expiratory volume (FEV_1) and the forced vital capacity (FVC), decreased with increasing age, increasing years of underground experience, and degree of dyspnea. The FVC was relatively normal in all four roentgenographic categories, but the FEV_1 was depressed in all categories, with the depression greater in those categories showing greater lung tissue involvement. No differences were seen between the suspect pneumoconiosis and simple pneumoconiosis categories. The FEV_1 was least depressed in the negative category, intermediate in the suspect and simple pneumoconiosis categories, and most depressed in the complicated pneumoconiosis category.

The comparable subject groups (working miners vs. nonminers) taking the work capacity test were equally capable of handling the work levels in the test, and the oxygen consumption per unit of body weight did not vary appreciably between groups of working individuals tested. The strain of handling the test levels of work did vary somewhat among individual subjects, and a certain percentage in each group did not complete the test. For various reasons, most of the nonworking miners did not participate in the work capacity test.

The study of Mullens, West Virginia, portion of the second population group (185 miners and their wives and 194 nonminers and their wives) indicated that an increase in nonspecific respiratory symptoms occurred in miners as compared with nonminers. In Mullens, the wives of coal miners also demonstrated an excess of nonspecific respiratory symptoms compared with wives of nonminers in the area. Although speculative comments about these findings can be made relating psychological or possible contaminating factors, no significant conclusions can be derived from the data at this time. There was, however, virtually no roentgenographic evidence of pneumoconiosis in nonminers or the wives of either miners or nonminers in Mullens. In contrast the study in Richwood, W. Va., indicated little difference in nonspecific respiratory symptoms between 175 miners and their wives and 153 nonminers and their wives.

The epidemiological research in coal workers' pneumoconiosis that has been carried out in this country and in Europe, especially in the United Kingdom, is reviewed, and an outline of the pathology of coal workers' pneumoconiosis is also included. The findings indicate that American bituminous coal miners show a disease pattern similar to that reported in European miners.

Environmental data for mines and mining communities that could be correlated with occupational history and physiological and roentgenographic changes were not included in this study.

CONCLUSIONS

(1) The 1963–65 prevalence study by the Public Health Service revealed that coal workers' pneumoconiosis is a serious widespread problem in Appalachia. Ten percent of the working miners and almost 20 percent of the nonworking miners showed roentgenographic evidence of this disease. About one-third of the working miners with definite roentgenographic evidence of disease showed complicated pneumoconiosis; almost one-half of the nonworking miners, roentgenographically classified as definitely having pneumoconiosis, showed complicated disease.

(2) Roentgenographic abnormalities are definitely related to coal mining and are not found in other workers living in the same area. The roentgenographic abnormalities also are clearly related to the number of years that a miner works underground as well as to specific mining jobs (face and transportation workers).

(3) The roentgenographic evidence of pneumoconiosis found in Appalachian bituminous coal miners resembles that described by British and European researchers.

(4) Nonspecific respiratory symptoms are not clearly related to coal mining although apparently chronic productive cough and dyspnea increase with increasing years underground. The data presented here indicate that dyspnea is associated more with age and cigarette smoking than with years underground, but underground mining experience may augment the extent of these symptoms.

(5) Ventilatory function values decrease with increasing age, cigarette smoking, number of years underground, and degree of dyspnea. The FVC was relatively normal in all four roentgenographic categories; the FEV_1 was depressed in all categories, however, with the depression being greater in those categories indicating greater lung tissue involvement.

(6) Miners did not vary appreciably from other workers with regard to their work capacity.

(7) Future studies of coal workers' pneumoconiosis should include environmental data.

Appendix 1.

Questionnaire Employed in Bituminous Coal Miners' Study

Budget Bureau No. 68-6252
Approval expires 12/31/64

UNITED STATES PUBLIC HEALTH SERVICE
DIVISION OF OCCUPATIONAL HEALTH

I-1. Survey No. ____________

I-2. Date ____________

I-3. Place ____________

I-4. In sample .... Yes ☐ No ☐

I-5. Now mining? .... Yes ☐ No ☐

I-6. Name of mine ____________

I-7. County allotment ____________

I-8. Reason for refusal ____________

____

IDENTIFYING INFORMATION AND RELEASE

I-10. Address ____________ (Last) ____________ (First) ____________ (Middle)

I-10. Address ____________ (Number and Street)

____________ (City) ____________ (State)

I-11. Birth date ____________ (Month-day-year) I-12. Age ______ (In years) I-13. Birthplace ____________ (State or Country)

I-14. Social Security No. ____________

Release: I hereby voluntarily agree to participate in a U.S. Public Health Service Study, which will include a chest X-ray examination and certain other medical tests. I authorize and request that any findings which the Public Health Service physician thinks should be referred to my personal physician be sent to Dr. ____________

whose address is ____________

____

(Signed) ____________

Interviewer ____________

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O–1. Survey No. ______________________

O–2. Name ______________________

OCCUPATIONAL HISTORY

(For questions O–3 through O–7, record answers in Table A)

O–3. Where are you now working?

O–4. In what year did you start working there?

O–5. Just what was your job there?

O–6. On the average, how many days per week did you work at that job?

O–7. Where did you work before your job at ______________________?
Specify previous job

O–8. In how many different mines have you worked?

Interviewer ______________________

O–1. Survey No. ____________

O–2. Name ____________

TABLE A.—*Occupational History*

Mine or industry and location	Years		Specific occupation	Occup code	Years in—			Days per week	Comments
	From	To			Coal mines	Other dusty	Non dusty		

TOTAL ____________

Worked in ____________ mines

Summary Table

Total years	Underground					Surface					
	Total	Face	Trans.	Main.	Misc.	Total	Trans.	Main.	Tipp.	Misc.	Oper.

Interviewer's initials ____________

BOB No. 68–6252
Approval Expires 12/31/64

H–1. Survey No. ______________________

H–2. Name ______________________

HEALTH QUESTIONNAIRE

(For questions H–3 through H–22, record answers in Table B)

H–3. Have you ever had, or been told you had, pneumonia?
H–4. Have you ever had, or been told you had, asthma?
H–5. Have you ever had, or been told you had, pleurisy?
H–6. Have you ever had, or been told you had, tuberculosis?
H–7. Have you ever had, or been told you had, heart trouble?
H–8. Have you ever had, or been told you had, dust on your lungs?

(If yes to any of questions H–3 through H–8, ask H–9 through H–13 for each condition. Record answers in Table B. If no to any of questions H–3 through H–8, fill in appropriate box in Table B.)

H–9. Was the (*condition*) diagnosed by a doctor?
H–10. About how old were you?

(If necessary, about what year was that?)

H–11. Did you ever have it at any other time?

(If more than once, show age or span of years.)

H–12. Did you ever have to stay in the hospital for it?

(If yes to H–12, ask H–13. If no, skip to next question.)

H–13. For about how long?
H–14. Have you ever had, or been told you had, bronchitis?

(If yes, to H–14, ask H–15 through H–20, and record answers in Table B. If no to H–14, fill in appropriate box in Table B and skip to H–21.)

H–15. Was it a doctor who diagnosed the bronchitis?
H–16. About how old were you?

(If necessary, about what year was that?)

H–17. Did you ever have it at any other time?

(If more than once, show each age. If at least one episode per year for the last 3 years, ask H–18.)

H–18. Did the coughing and phlegm stop completely between attacks?

(Record answer to H–18 in box marked "Acute rec." in Table B.)

H–19. Did you have to stay in a hospital for it?

(If yes to H–19, ask H–20. If no, skip to H–21.)

H–20. For about how long?
H–21. Have you ever had any other chest or lung trouble which hasn't been mentioned yet—even if you didn't see a doctor about it?

(If yes to H–21, ask H–22, and H–9 through H–13 when appropriate. If no, skip to H–23.)

H–22. What was the chest trouble?

TABLE B.— *History of Specific Conditions.*

Condition	Has not had	MD Dx	Ages	Hospitalization: None	Hospitalization: Week or more	Hospitalization: Less than week
Pneumonia						
Asthma						
Pleurisy						
Tuberculosis						
Heart trouble						
Dust on your lungs						
Bronchitis			Acute rec. Yes ☐ No ☐			
Other chest trouble .... Specify						

Recent Chest Illness

H–23. Including those conditions mentioned already, have you had any chest illnesses *during the past 3 years* which kept you away from work or away from your usual activities? Yes ☐ No ☐

(If yes to H–23, ask H–24 through H–28, and record answers in Table C. If no to H–23, skip to H–29.)

H–24. What year was that in?
H–25. What did the doctor say it was?
H–26. If no doctor diagnosed the condition, what do you think was wrong with you?
H–27. About how long did it keep you away from your work or usual activities?
H–28. Did it make you bring up phlegm from your chest *more than usual?*

TABLE C.—*Chest Illnesses During Past 3 Years.*

Year	Diagnosis		Duration		Phlegm	
	By doctor	Not by doctor	More than a week	Less than a week	Yes	No

H–29. Have you ever been badly affected by breathing gas or fumes? Yes ☐ No ☐

(If yes to H–29, ask H–30 through H–34. If no, skip to H–35.)

H–30. What happened? ______

H–31. How were you affected? ______

H–32. How old were you at the time?

Age ☐

H–33. Did you have to stay in a hospital for that? Yes ☐ No ☐
(If yes to H–33, ask H–34. If no, skip to H–35.)

H–34. For about how long? Days ☐

H–35. Do you ever have swelling of the ankles? Yes ☐ No ☐
(If yes to H–35, ask H–36. If no, skip to H–37.)

H–36. When and how often did this occur? ______

Cough

H–37. In the winter, do you usually cough when you get up, or first thing in the morning? I don't mean just clearing your throat or one cough, but more than that. Yes ☐ No ☐
(If yes to H–37, ask H–38 through H–40. If no, skip to H–41.)

H–38. Do you usually go on coughing during the day or at night? Yes ☐ No ☐

H–39. Thinking about this cough of yours, do you cough like that on most days for as much as 3 months each year? Yes ☐ No ☐

H–40. For about how many years have you been coughing like that? Years ☐

Phlegm

H–41. In the winter, do you usually bring up phlegm when you get up or the first thing in the morning? I don't mean from the back of your nose, but from your chest? Yes ☐ No ☐
(If yes to H–41, ask H–42 through H–44. If no, skip to H–45.)

H–42. Do you usually go on bringing up phlegm at other times during the day or night? Yes ☐ No ☐

H–43. Do you bring up phlegm on most days for as much as 3 months each year? Yes ☐ No ☐

H–44. For about how many years have you been bringing up phlegm like that? Years ☐

Hemoptysis

H–45. Have you ever coughed up blood? Yes ☐ No ☐
(If yes to H–45, ask H–46 and H–47. If no, skip to H–48.)

H–46. When was that? ______

H–47. Did you cough up just a few streaks of blood or more than that? Few ☐ More ☐

WHEEZING

H–48. Does your chest ever sound wheezy or whistling? Yes ☐ No ☐

(If yes to H–48, ask H–49 and H–50. If no, skip to H–51).

H–49. Is that only with colds or at other times, too? Other times ☐ Colds only ☐

(If "Other times" is checked, ask H–50. If not, skip to H–51.)

H–50. Do you get this most days or nights or just once in a while? Most times ☐ Rarely ☐

☐

BREATHLESSNESS

(If respondent is unable to walk due to any condition other than heart or lung disease, check box and skip to H–55.) Disabled ☐

H–51. Do you ever get short of breath when you hurry on the level or walk up a slight hill? Yes ☐ No ☐

(If yes to H–51, ask H–52. If no, skip to H–55.)

H–52. Do you ever get short of breath walking with other people *your own age* at an ordinary speed on the level? Yes ☐ No ☐

(If yest to H–52, ask H–53. If no, skip to H–55.)

H–53. Do you have to stop for breath when walking *at your own speed* on the level? Yes ☐ No ☐

(If yes to H–53, ask H–54. If no, skip to H–55.)

H–54. Do you get short of breath when you wash or dress? Yes ☐ No ☐

☐

WEATHER

H–55. Does the cold, damp, or foggy weather affect your chest? Yes ☐ No ☐

(If yes to H–55, ask H–56 and H–57. If no, skip to H–59.)

H–56. Does it make you short of breath? Yes ☐ No ☐

H–57. Does it affect your chest in some other way? Yes ☐ No ☐

(If yes to H–57, ask H–58. If no, skip to H–59.)

H–58. How? ______________________________

____

____

____

GENERAL HEALTH

H–59. How would you say your general health is right now? ______________________________

____

____

____

RACE (Observe: do not ask.)

H–60. White ☐ Negro ☐
Other (Specify) ____________________

COMMENTS

H–61. General Comments ____________________ Interviewer's Initials ______

S–1. Survey No. ____________

S–2. Name ____________

SMOKING QUESTIONNAIRE

S–3. Have you ever smoked cigarettes? Yes ☐ No ☐
(If yes to S–3, ask S–4. If no, skip to S–11.)

S–4. Do you smoke cigarettes now? Yes ☐ No ☐
(If yes to S–4, ask S–5 through S–7. If no, ask S–8 through S–10.)

S–5. About how many cigarettes a day do you usually smoke? Number ☐

S–6. Do you inhale—I mean draw the smoke into your chest? Yes ☐ No ☐

S–7. For about how many years have you smoked cigarettes? Years ☐
(Skip to S–11.)

S–8. When you used to smoke, about how many cigarettes a day did you usually smoke? Number ☐

S–9. Did you inhale—I mean draw the smoke into your chest? Yes ☐ No ☐

S–10. For about how many years did you smoke cigarettes? Years ☐
(Go on to S–11.)

S–11. Have you ever smoked cigars? Yes ☐ No ☐
(If yes to S–11, ask S–12 through S–14. If no skip to S–15.)

S–12. Do you smoke cigars now? Yes ☐ No ☐
(If yes to S–12, ask S–13 and S–14. If no, skip to S–15.)

S–13. About how many cigars a day do you usually smoke? Number ☐

S–14. For about how many years have you smoked cigars? Years ☐

S–15. Have you ever smoked a pipe? Yes ☐ No ☐
(If yes to S–15, ask S–16 through S–18. If no, end interview.)

S–16. Do you smoke a pipe now? Yes ☐ No ☐
(If yes to S–16, ask S–17 and S–18, If no, end interview.)

S–17. About how many pipefulls of tobacco do you usually smoke a day? Number ☐

S–18. For about how many years have you smoked a pipe? Years ☐

S–19. Have you ever chewed tobacco? Yes ☐ No ☐

S–20. Do you chew tobacco now? Yes ☐ No ☐
If yes to S–20, ask:

S–21. About how many plugs do you chew a week? Number ☐

S–22. For about how many years have you chewed tobacco? Number ☐

Appendix 2. *Household Interview Questionnaire*

Budget Bureau No. 68–6354
Approval Expires 12/31/63

ORC 900–K
083063

Opinion Research Corporation Acting as Collecting Agent for the U.S. Public Health Service Division of Occupational Health

Assignment #________ Household #________ Questionnaire #______ of ______ questionnaires.

Address (or description of location) ____________________.

Good (morning, afternoon). I am ________________ of the Opinion Research Corporation. We are making a survey of the health of people in ____________ County for the Public Health Service. Will you please tell me:

1a. What is the name of the head of this household?
b. Is he at home now? IF YES: May I speak to him? (Interview head of household if available. OTHERWISE, CONTINUE INTERVIEW WITH ANY ADULT MEMBER OF FAMILY.)

2a. What are the names of all other persons who live here?
b. I have listed (read names). Is there anyone else staying here now, such as friends, relatives, or roomers?
c. (FOR EACH ADDITIONAL PERSON NAMED): Does he (she) usually live here or someplace else? LIST IN TABLE IF "USUALLY LIVE HERE."
d. Have I missed anyone who usually lives here, but is now—

Temporarily in a hospital	No ( )	Yes ( )
Away on business?	No ( )	Yes ( )
On a visit or vacation?	No ( )	Yes ( )
Away for some other reason?	No ( )	Yes ( )

3. How are you (is he, she) related to the head of the household? (ENTER RELATIONSHIP TO HEAD, FOR EXAMPLE: WIFE, SON-IN-LAW, ROOMER.)

4. How old were you (was he, she) on your (his, her) last birthday? (IF NOT ALREADY KNOWN, DETERMINE WHICH PERSONS AGE 21 OR OVER ARE AT HOME NOW.)

5. INTERVIEWER MARK (type of living quarters):

House	( )	Other housing unit	( )
Apartment	( )	Nonhousing unit	( )

6. Race: White ( ) Negro ( ) Other ( )
(ASK QUESTIONS 7 AND 8 IF NOT DEFINITELY KNOWN FROM PREVIOUS ANSWERS.)

7. Sex: (MARK ONE ANSWER FOR EACH PERSON.)

8. Are you now married, widowed, divorced, separated, or never married?
(MARK ONE ANSWER FOR EACH PERSON.)

9. What were you doing most of the past 12 months . . .
FOR MALES: Working, or doing something else?
FOR FEMALES: Keeping house, working, or doing something else?

(BEGINNING WITH QUESTION 10 YOU ARE TO INTERVIEW FOR HIMSELF OR HERSELF, EACH ADULT WHO IS AT HOME NOW.)

These next few questions deal with you, your ________, etc.

10. Since this time last year, have you (your ________, etc.), had any of these conditions?

(READ) FOLLOWING LIST, *ONE CONDITION AT A TIME*, PAUSING AFTER EACH. BE SURE TO ASK EACH PERSON PRESENT EACH ITEM ON THE LIST. REMIND THEM AFTER EVERY FEW ITEMS TO THINK ABOUT ABSENT FAMILY MEMBERS AS WELL—i.e., "YOU, YOUR ________, ETC." MARK ANY CONDITIONS MENTIONED IN THE COLUMN FOR THE PERSON WHO HAD IT.)

1. Asthma
2. Bronchitis
3. Emphysema
4. Silicosis, or rock dust on the lungs
5. Pleurisy
6. Pneumonia
7. Sinus trouble
8. Tuberculosis—TB
9. Mental illness
10. Arthritis or rheumatism
11. Bursitis, big knee or miner's knee
12. Hernia or rupture
13. Heart trouble
14. A stroke
15. A cyst, a tumor or a growth
16. Cancer
17. High blood pressure
18. Nervous trouble
19. Skin trouble
20. Ulcer

(IF RESPONDENT IS UNCERTAIN ABOUT THE NAME OF A CONDITION, BUT THINKS THAT IT MAY BE RELATED TO ONE OF THE 20 CONDITIONS LISTED, MARK THE "OTHER RELATED CONDITION" ANSWER AND SPECIFY THE WAY IN WHICH RESPONDENT REFERS TO IT.)

11a. Since this time last year, have you, your ________, etc., had any injuries from accidents that interfered with things you usually do, or which just bothered you, for more than a week?

IF "YES" ON QUESTION 11a, ASK:

b. Who was injured?
c. What kind of injury was it?
d. Did any of you have any other injuries since this time last year that bothered you for more than a week?

12a. Have you *ever* had an (any other) injury from an accident that still bothers you or affects you in any way?

IF "YES" ON QUESTION 12a, ASK:

b. In what way does it bother you? (RECORD PRESENT EFFECTS.)
c. Any other accident?

13. Again, referring to you, your ________, etc, does any one of you have any of these conditions *now?*

(READ THE FOLLOWING LIST, *ONE IMPAIRMENT AT A TIME,* PAUSING AFTER EACH. BE SURE TO ASK EACH PERSON PRESENT EACH ITEM ON THE LIST. REMIIND THEM AFTER THE THIRD ITEM TO THINK ABOUT ABSENT FAMILY MEMBERS AS WELL—"YOU, YOUR ________, ETC." MARK THE IMPAIRMENT MENTIONED IN THE COLUMN FOR THE PERSON WHO HAS IT.)

1. Deafness or serious trouble *hearing* with one or both ears.
2. Serious trouble *seeing* with one or both eyes even when you are wearing glasses.
3. *Paralysis* of any kind.
4. Repeated trouble with your *back or spine.*
5. *Missing* fingers, hand or arm—or missing toes, foot or leg.
6. Permanent *stiffness* of your hand, arm, foot, leg or back.

14a. *In the winter,* do you usually cough when you get up, or the first thing in the morning—I don't mean just clearing your throat or one cough, but more than that?

IF "YES" ON QUESTION 14a, ASK:

b. Do you usually go on coughing during the day or at night?
c. Do you cough like that most days for as much as 3 months each year?
d. For about how many years have you been coughing like that?

(IF "DON'T KNOW HOW MANY YEARS," PROBE: Would you say 1 or 2 years, or more than that?)

15a. In the winter, do you usually bring up phlegm or mucus when you get up or the first thing in the morning—I don't mean from the back of your nose, but from your chest?

IF "YES" TO QUESTION 15a, ASK:

b. Do you usually go on bring up phlegm (mucus) during the day or at night?
c. Do you bring up phlegm (mucus) like that on most days for as much as 3 months a year?
d. For about how many years have you been bringing up phlegm (mucus) like that? (IF "DON'T KNOW HOW MANY YEARS," PROBE: Would you say just 1 or 2 years, or more than that?)

16a. Do you ever get short of breath when you walk fast on level ground, or when you walk up just a little hill? (IF "NO," FILL OUT ITEM R. BELOW.)

IF "YES" ON QUESTION 16a, ASK:

b. Do you ever get short of breath when you walk at an ordinary speed on level ground with other people your *own age*? (IF "NO," FILL OUT ITEM R. BELOW.)*

IF "YES" ON QUESTION 16b, ASK:

c. Do you ever have to stop to get your breath when walking at your own pace on level ground? (IF "NO," FILL OUT ITEM R. BELOW.)*

IF "YES" ON QUESTION 16c, ASK:

d. Do you ever get short of breath when you wash or dress? (FILL OUT ITEM R. BELOW.)

(*IF "YES" ON QUESTION 16b, BE SURE TO ENTER "BREATHLESSNESS" IN TABLE A.)

R. for Q. 10–16 SHOW WHO RESPONDED FOR QUESTIONS 10–16. IF PERSON RESPONDED FOR SELF, SHOW WHETHER WHOLLY OR PARTLY.

17a. Here is a list of conditions that many people have once in a while. You (may) have mentioned some of these already, but this is the place where we have to be sure to mark them down. As I read them, please tell me for each one whether this is something *you* have fairly often, once in a while, or practically never.

(READ SYMPTOMS LISTED BELOW, ONE AT A TIME, PAUSING AFTER EACH. IF ANSWER IS "FAIRLY OFTEN" ASK):

b. In the last 2 weeks—that is, in the 14 days since the (day of week) before last, on about how many different days did you have . . . ?

1. Headache or pains in the head
2. Backache or pains in the back
3. Pains in the stomach
4. Pains in the chest
5. Pains in the joints
6. Feeling dizzy
7. Cold sweats
8. Heartburn
9. Gas
10. Constipation
11. Acid or sour stomach
12. Trouble falling asleep, or waking up at night and not being able to get back to sleep
13. Tired, worn-out feeling even after a night's sleep
14. No appetite for food
15. Tingling feeling in your* hands or face
16. Numbness or no feeling in your* hands or face
17. Feeling so nervous and fidgety that you* can't sit still
18. Sudden pounding or fast beating of your* heart, when you're not working hard or exercising
19. Sudden feeling that you* can't get your* breath when you're not working hard or exercising
20. Having your* hands tremble so much that it bothers you*

(REPEAT ABOVE FOR EACH ABSENT FAMILY MEMBER OVER 21. *SUBSTITUTE "HE," "SHE," "HIS," "HER," ETC., AS APPROPRIATE.)

18a. Since this time last year, have you, your ____________, etc., been a patient in a hospital for overnight or longer?

IF "YES" ON QUESTION 18a, ASK:

b. Who was that?

c. How many times were you (was he, she) in the hospital?

d. All together, how many days were you in the hospital since this time last year?

e. Anyone else? (IF "YES," REPEAT Q. 18b, c, d and e, UNTIL THE ANSWER ON Q. 18e IS "NO.")

19a. Since this time last year, have you, your ____________, etc., been a patient in a rest home or a nursing home or any similar place?

IF "YES" ON QUESTION 19a, ASK:

b. Who was that?

c. How many times?

d. All together, how many days were you there since this time last year?

e. Anyone else? (IF "YES," REPEAT Q. 18b, c, d, and e, UNTIL THE ANSWER ON Q. 19e IS "NO.")

R. for Q. 17–19 SHOW WHO RESPONDED FOR QUESTIONS 17–19. IF PERSON RESPONDED FOR SELF, SHOW WHETHER WHOLLY OR PARTLY.

These next questions are about how people get medical care.

20. Which do you feel makes better sense . . .
    —Talk to you doctor as soon as you don't feel well, or
    —To have him examine you every so often even if you feel perfectly all right?

21. When you feel sick, which of these do you usually do . . .
    —Talk to a doctor as soon as you don't feel well, or
    —Wait until you're really seriously sick?

22. How often do you *usually* talk to a doctor about your health?

23. When did you *last* talk to a doctor about your health?
    (PROBE: Was it within the last year?)

24a. What was it for—was it . . .
    —To be examined or treated for some sickness or other condition?
    —For a general checkup?
    —Something else?

25. What is the name of the doctor you talked to then? (INCLUDE FIRST NAME OR AT LEAST INITIALS.)

26. Where is his office?

27a. Since this time last year, have you, your ____________, etc., gotten any health advice or care from anyone other than a physician?

IF "YES" ON QUESTION 27a, ASK:

b. Who was that? (ENTER IN THE COLUMN OF THE PERSON WHO GOT THE ADVICE OR CARE, THE NAME AND DESIGNATION OF THE ONE WHO GAVE IT.)

28a. Since this time last year, has any one of you wanted to get any kind of health care which you didn't get, such as . . .

—Medicine	—Hospitalization	—Nursing
—Doctor's treatment	—Dental care	—Any other

IF "OTHER" ON QUESTION 28a, ASK:

b. What was that?

IF "YES" TO ANY ITEMS ON QUESTION 28a, ASK:

c. Why didn't you get it?

(IF MORE THAN ONE KIND OF HEALTH CARE NOT OBTAINED, ASK SEPARATELY ABOUT EACH KIND OF CARE, AND USE LETTER CODE BELOW TO RECORD ANSWER.)

A. Can't afford, no money
B. Too busy, no time
C. That type of person or service not available or inaccessible
D. Other answer (WRITE REASON IN ANSWER COLUMN)

Now I have some questions to ask you about smoking.

29. Have you ever smoked cigarettes?

IF "YES" ON QUESTION 29, ASK:

30. Do you smoke cigarettes now?

31. About how many cigarettes a day do you usually smoke?

32. Do you inhale—I mean draw the smoke into your chest?

33. For about how many years have you smoked cigarettes?

34a. Have you ever smoked more cigarettes a day than you do now?

"IF YES" TO QUESTION 34a, ASK:

b. About how many a day?
c. For about how many years?

IF "NO" TO QUESTION 30, ASK:

35. When you used to smoke, about how many cigarettes a day did you smoke?

36. Did you inhale—I mean draw the smoke into your chest?

37. For about how many years did you smoke cigarettes?

38. Have you ever smoked cigars?

39a. Do you smoke cigars now?
IF "YES" ON QUESTION 39a, ASK:
b. About how many cigars a day do you usually smoke?
c. For about how many years have you smoked cigars?

40. Have you ever smoked a pipe?

41a. Do you smoke a pipe now?
IF "YES" ON QUESTION 41a, ASK:
b. About how many pipefuls of tobacco a day do you usually smoke?
c. For about how many years have you smoked a pipe?

42. Have you ever chewed tobacco?

43a. Do you chew tobacco now?
IF "YES" ON QUESTION 43a, ASK:
b. About how many plugs do you chew a week?
c. For about how many years have you chewed tobacco?

44. What is the last grade you completed in school?

R. for Q. 20–44 SHOW WHO RESPONDED FOR QUESTIONS
20–44. IF PERSON RESPONDED FOR SELF, SHOW WHETHER WHOLLY OR PARTLY.

IF NO MALE 21 OR OVER IN FAMILY, GO TO QUESTION 57. COMPLETE QUESTIONS 45–66 FOR EACH MALE 21 OR OVER.

The next questions are about where the men in your family have lived and the kind of work they have done.

45. In what State or country were you (was your ________) born?

Not in United States ......( )
Country ________

In United States, but not not West Virginia State ....( )

In West Virginia ....( )

IF NEGRO, GO TO Q. 47

46a. In about what year did you come to the United States

46b. What nationality was your family originally?
English, Irish, Scotch, or Welsh ....( )
Other ....( )
Specify: ________
IF MORE THAN ONE NATIONALITY:

46c. Which one of these was most important in your family?

47. In about what year did you come to West Virginia?

48a. Have you lived in this part of West Virginia all of your life since then?
Yes ....( )
No ....( )
IF "NO" TO QUESTION 48a, ASK:

48b. Where else have you lived for periods of at least 5 years?

48c. In about what years did you live there?

48d. Anyplace else?

49a. Did you work at any time last week or the week before?
Yes ....( )
No ....( )

49b. Even though you didn't work last week or the week before, do you have a job or business?
Yes ....( )
No ....( )

49c. Were you looking for work or on a layoff from a job?
Yes ....( )
No ....( )

IF "YES" TO 49b or 49c, GO TO QUESTION 50: IF "NO" to BOTH 49b *AND* 49c, CONTINUE WITH NEXT QUESTION:

49d. Have you had a job or business in the past?
Yes ....( )
No ....( )

IF "YES" ON 49d, GO TO QUESTION 54a.
IF "NO" ON 49d, GO TO QUESTION 56.

ASK FOR PRESENT JOB OR LAST FULL-TIME JOB:

50. For whom do (did) you work?

____
(name of business firm)

51. What kind of business or industry is it?
Coal mining ....( )
Railroad ....( )
Other ....( )
Specify: ______________________

52. What kind of work do you do (did you do) in your last job?

53. Is that the kind of work you have usually done?
Yes ....( )
No ....( )

For about how many years? ______________
GO TO QUESTION 55a.

54a. What kind of work have you usually done?

____

b. What kind of business or industry was that usually in?
Coal mining ....( )
Railroad ....( )
Other ....( )
Specify: ______________________

c. For about how many years did you do that?
______________ years

d. About what year did you last do that?

IF COAL MINING HAS NOT BEEN MENTIONED, ASK:

55a. Have you ever worked in coal mining?
Yes ....( )
No ....( )

b. What kind of work did you do?

c. For about how many years did you do that?
______________ years

d. About what year did you last do that?
______________ years

ASK EVERYONE:

56. Now I'd like to ask about the kind of work your (his) father did—most of his life did he work in coal mining, railroading, farming, or something else?
______________ years
Coal mining ....( )
Railroad ....( )
Farming ....( )
Something else ....( )
What? ______________________

IF HEAD AND SPOUSE ARE 35 OR OVER ASK:

57a. Have you any children over 18 years old who don't live with you? Yes ( )
No ( )
GO TO QUESTION 58

RECORD ANSWERS TO REMAINING QUESTIONS IN THIS COLUMN IN TABLE BELOW.

b. What are their first names?

c. In what city or state does ______________ live?

1. Mullens or Richwood
2. Wyoming or Nicholas
3. Other, W. Va. County
4. Chicago, Ill.
5. Cincinnati, Ohio
6. Detroit, Mich.
7. New York, N.Y.
8. Pittsburgh, Pa.
9. Washington, D.C.

IF PLACE OF RESIDENCE IS LISTED HERE, PUT CODE NUMBER IN ANSWER SPACE BELOW. OTHERWISE, FILL IN CITY OR TOWN AND STATE.

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d. Is ________________ working or something else?
(IF "SOMETHING ELSE") : What?
(IF "WORKING") : What kind of work does ________________ do? In what kind of business or industry is that?
ASK EVERYONE:

58. Do you own or rent your home here?
Own ( )
Rent ( )
Other ( )

59. How many rooms do you have? (not counting bathrooms) ________________ rooms.

60. In which of these groups is the total income of all members of your family for the past 12 months—that is yours, your ________________, etc? That includes wages and salaries, social security or retirement pay, workmen's compensation, welfare payments, etc.
SHOW RESPONDENT INCOME CARD B AND READ IT ALOUD.

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