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THE APPALACHIAN COAL MINER MORTALITY STUDY: A 14-YEAR FOLLOW-UP

Report to the Director, NIOSH

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16. Abstract (Limit: 200 words)

From 1963 to 1965, the U.S. Public Health Service examined 3,726 underground Appalachian bituminous coal miners who were living in 1962. Their vital status was verified on January 1, 1973 (10 years of follow-up) and again on January 1, 1976 (14 years of follow-up). Mortality was studied after 10 years and results were published by Ortmeyer (1974) and Costello (1974, 1975). The results of a study of the mortality after 14 years are the subject of this report. As of January 1, 1976, 25 persons were lost to follow-up, 843 had died, and 2,850 were living. Eight were found living during the follow-up period, but their vital status was unknown on January 1, 1976. Death certificates were obtained on all but 51 of those who had died and on these the date of death was verified.

The cause of death was determined from the underlying cause recorded on the death certificate. Death from all causes, ischemic heart disease, non-malignant respiratory disease (NMRD), cancer of the trachea, bronchus, and lung, digestive cancer, and accidents were studied. Except for lung cancer, the results were similar to those previously reported by Ortmeyer and Costello.

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THE APPALACHIAN COAL MINER MORTALITY STUDY: A 14-YEAR FOLLOW-UP

ABSTRACT

From 1963 to 1965, the U.S. Public Health Service examined 3726 underground Appalachian bituminous coal miners who were living in 1962. Their vital status was verified on January 1, 1973 (10 years of follow-up) and again on January 1, 1976 (14 years of follow-up). Mortality was studied after 10 years and results were published by Ortmeyer (1974) and Costello (1974, 1975). The results of a study of the mortality after 14 years are the subject of this report. As of January 1, 1976, 25 persons were lost to follow-up, 843 had died, and 2850 were living. Eight were found living during the follow-up period, but their vital status was unknown on January 1, 1976. Death certificates were obtained on all but 51 of those who had died and on these the date of death was verified.

The cause of death was determined from the underlying cause recorded on the death certificate. Death from all causes, ischemic heart disease, non-malignant respiratory disease (NMRD), cancer of the trachea, bronchus, and lung, digestive cancer, and accidents were studied. Except for lung cancer, the results were similar to those previously reported by Ortmeyer and Costello.

The risk of death increased with age and cigarette smoking in ex-miners, and with the occurrence of progressive massive fibrosis (PMF), dyspnea, and airways obstruction, but not with simple pneumoconiosis. Risk of death from ischemic heart disease increased with age, cigarette smoking, mining status, tenure in dusty jobs other than in coal mining, dyspnea, airways obstruction, and weight, but was not associated with coal mine dust exposure.

The risk of death from a nonmalignant respiratory disease increased with age, smoking, PMF, and in ex-miners. In addition, the combined effect of ex-smoking and radiographic evidence of simple pneumoconiosis was associated

with an increased risk. Risks were not excessive for those who had never smoked nor those without airways obstruction. The risk of death from digestive cancer was only related to age, and the risk from accidents was higher among miners than ex-miners, but neither was associated with coal mine dust exposure.

The most provocative finding of this study was the results for lung cancer. The risk of death from lung cancer increased with radiographic category of pneumoconiosis but only among current smokers. The number of nonsmokers with pneumoconiosis were too small to separate the effects of smoking and radiographic category. However, results from the regression model and the standardized mortality ratio were similar. An excess of deaths was not found in the total group nor among nonsmokers, however, it increased with radiographic category, particularly among those who had smoked greater than 40 pack years.

THE APPALACHIAN COAL MINER MORTALITY STUDY: A 14-YEAR FOLLOW-UP

INTRODUCTION

This is a report on the cause-specific mortality of a cohort of former and active coal miners over a 14 year period. The purpose of this study was two-fold. First, Standardized Mortality Ratios and life table regression models were derived to control for the contribution of risk factors to cause-specific mortality and to evaluate the effect of coal mine dust exposure. Second, the results were compared to those published after 10 years of follow-up (Costello, 1974,1975; Ortmeyer, 1974). The four additional years of follow-up provided the potential to document new associations between coal mine dust exposure and certain specific causes of death.

A Review of Coal Miner Mortality Studies

Table 1 summarizes the literature to 1981. The association between excess mortality and coal mine dust exposure is described below for all causes, lung cancer, stomach cancer, nonmalignant respiratory disease, and simple pneumoconiosis.

All Cause Mortality

Carpenter (1956) considered the mortality from all causes of the population of the Rhonda Fach and observed an SMR of 123 for males and 102 for females. He believed the elevated male/female ratio indicated an occupational effect. Cochrane (1964) in a six-year follow-up of this group found an SMR of 143.4 for miners and ex-miners. In both studies miners had higher SMR's than non-miners. Liddell (1973) in a cross-sectional study, compared miners of England and Wales to employed and retired male non-miners. He found excess mortality only among surface workers, concluding that underground workers must be healthier. Higgins (1968) surveyed the Stavely, England, population and found that death rates were similar for miners and non-miners (workers in non-dusty trades) for ages 25-34 and 55-64. This finding was also confirmed by Cochrane (1980a,b) in a 20-year follow-up of Stavely. Moreover, Stavely miners had a lower death rate than non-miners. Cochrane (1979) also published a 20-year follow-up of the Rhonda Fach survey, showed excess mortality, and speculated that Stavely miners may have had less dust exposure.

Mortality statistics on U.S. miners are conflicting. Enterline (1964, 1972) in cross-sectional studies of U.S. working males (census data) and insurance policy holders found significant excesses in deaths from all causes. However, Ortmeyer (1974) in a 10-year follow-up of Appalachian coal miners, and Rockette (1977) in a 12-year follow-up of miners paying dues to the United Mine Workers of America, found no excess deaths. Ortmeyer speculated that the discrepancies among the studies' results may be due to:

(1) Misclassification of coal miners and ex-miners on 1950 death certificates and census records used by Enterline.

(2) A higher death rate in Ortmeyer's 6% lost to follow-up than in the study population. However, this is not likely to account for the extreme difference in SMR's published by Ortmeyer and Enterline.

(3) A faster downward trend in death rates for coal miners than for all U.S. males from 1950 to 1971.

(4) Ortmeyer studied bituminous miners but the 1950 population included anthracite workers; Enterline's miners included both groups.

Errors in coding of occupation may partially explain the excesses reported by Carpenter and Liddell. Heasman (1958) found that numerator data from 'official records' (e.g., death certificates or sickness benefit records) and denominator data from the census is subject to error. He studied the accuracy of the numerator data by comparing 'official records' to 'independent' data obtained from the National Coal Board, pension funds, records of district medical officers, and inquiries at pits where men worked. He found that 27.9% more face workers and 24.1% less surface workers were reported as deceased by official records than independent data. Among retired miners, 30% had held other jobs before leaving mining and their death certificates listed their last job as either retired or as a coal miner. He defined the net overall misclassification as the 'promotion' effect into face worker and supervisor categories and this was estimated to be 12-15%.

Heasman also selected a sample of 3745 men from NCB records to verify census records (denominator data). He found agreement as to occupation in two-thirds of the cases. Promotion to face workers was 5% and demotion to surface occupations was 18%, a 1.7% overall promotion.

Using his promotion results, he calculated adjusted SMR's for all cause mortality. He found among all miners the unadjusted SMR for 1955 was inflated 17% (SMR (adj) = 100 and SMR (unadj) = 117) and no excess mortality was indicated. Unadjusted SMR's were inflated 75% (81 to 142) among underground workers and under-reported for surface workers (135 versus 109).

Liddell (1973) conducted similar comparisons in a 5% sample of the 1961 British coal miner population and again found a 15.6% promotion effect overall, ranging from 9.6% to 37.7% over nine districts, and directly associated with age.

Pneumoconiosis

Pneumoconiosis has of course been of primary concern among coal miners. It is characterized radiologically in its early stages as small opacities (less than one cm in diameter) which increase in size and profusion with continuous dust exposure (Morgan, 1975). In its later stages it is characterized by opacities greater than one cm and this condition has been referred to as progressive massive fibrosis (PMF) and complicated pneumoconiosis.

The ILO-U/C classification (ILO-U/C Committee, 1971), has been frequently used to classify the size and profusion of small opacities. Two types are defined, rounded and irregular, each of which are classified into three divisions based on size. Profusion is classified into four discrete categories: 0, 1, 2, and 3. Categories 1, 2, and 3 are referred to as simple pneumoconiosis and correspond to a scale of increasing profusion of opacities per unit area on the radiograph. The profusion scale has been correlated with lifetime dust exposure (Jacobson, 1970), with weight of coal mine dust constituents in the lung (Liddell, 1972), and total years worked underground. Morgan (1975) noted that the scale is an epidemiological measure of dust retention in the lung. Large opacities, on the other hand, are divided into stages A, B, and C, based on size, and may progress independently of further dust exposure (McLintock, 1971).

Most studies have shown that marked excess mortality is only associated with PMF (stage B and C). Among miners with category 0-3, Carpenter (1956) found moderate excesses (SMR = 100-138) as did Cochrane in his six-year and 20-year follow-up of the Rhonda Fach. Higgins (1972) found similar rates in the Stavely population between non-miners and miners with categories 0-3, and Cochrane confirmed this in his 20-year follow-up. Ortmeyer found moderate excesses among ex-miners with simple CWP (SMR = 119-129) but no excess mortality among working miners over his 10-year follow-up period. Ortmeyer's data also suggested an interaction between pneumoconiosis category and cigarette smoking, bronchitis, and airways obstruction.

Nonmalignant Respiratory Disease

British and U.S. studies generally indicated excess mortality from respiratory diseases such as bronchitis and tuberculosis. Higgins (1968, 1972) in a nine-year follow-up of the Stavely miners found excess mortality in miners who complained of symptoms of chronic bronchitis on their initial exam. Similar associations were reported by Ortmeyer in the Appalachian Coal Miner Study; Enterline (1972) in a 28 1/2-year follow-up of a Beckley, West Virginia cohort; and Cochrane in a 20-year follow-up of the Rhonda Fach. However, Rockette found no excess death from bronchitis in a 12-year follow-up. Liddell only found excess mortality among surface workers, and Ortmeyer found an excess only among workers with category 0 and PMF. Indeed chronic bronchitis likely increases the risk of mortality. Rockette and Liddell, however, presented the risk of death from bronchitis rather than the risk of death from any cause given bronchitis at the time of entry into the study. Based on the mortality studies of Higgins, Ortmeyer, and Cochrane, the latter risk may be in excess, while the former may be under-estimated since chronic bronchitis is not likely to be recorded on the death certificate as an underlying cause of death.

Only Higgins and Ortmeyer considered cigarette smoking, and claimed that its effect on mortality was greater than that of coal mine dust exposure (measured by x-ray category of pneumoconiosis). However, a problem in most mortality studies has been insufficient data to control for smoking, age, and tenure simultaneously. It is widely accepted that smoking and coal mine dust exposure cause respiratory disease; however, more work is required to identify possible synergistic effects. Regression techniques may be useful in this regard.

Lung Cancer

The association between coal mining and lung cancer has yet to be substantiated. Different results and interpretations from studies have likely been due to the lack of control for potentially confounding risk factors such as smoking, genetics, ethnicity, migration, socio-economic status, and other occupational exposures (e.g., to asbestos, chloromethyl ethers with bischloromethyl ether, polycyclic aromatic hydrocarbons, and metals such as nickel and chromium) (Waxweiller, 1978).

A significant excess lung cancer mortality was found by James (1955) (SMR = 121-177 for simple pneumoconiosis); Rooke (1979)(SMR = 125-129 for simple pneumoconiosis), Enterline (1964)(SMR = 192), and Enterline (1972) (SMR = 260). However, only slightly elevated SMR's were reported by Rockette (1977)(SMR = 113) and Enterline (1972)(SMR = 110-115), and deficits were noted by Costello (1974)(SMR = 67), Liddell (1973)(SMR = 49-82), Kennaway (1937, 1947)(SMR = 59), Doll (1958)(SMR = 48), Goldman (1965)(SMR = 81), and Cochrane (1979(SMR = 68-80). Ames (1982b) found the odds ratio for lung cancer due to coal mine dust exposure was only elevated among long-term smokers, but did not reach statistical significance. His results were from a case-control study using cases from 4 coal mine cohorts.

Stomach Cancer

The role of coal mining in causing stomach cancer is also speculative since studies have not considered risk factors such as place of residence, ethnicity, sex, social class, migration, dietary factors, and blood type (Ames, 1982a; Blum, 1978). Enterline reported markedly elevated SMR's for digestive cancer. Stocks (1972) showed an excess which may not indicate an occupational effect since it was found for miners and their wives. Rockette (1977) noted a moderate SMR (138) for stomach cancer but low SMR's for digestive cancer (94). Liddell (1973) reported an excess only in underground workers, but not among face workers who have the highest dust exposures. Matalo (1972), in an ecological study of three counties in Utah (two with coal mining and one without mining), noted an excess in males but not females over a four-year period (1965-67). Klauber (1978), however, repeated a survey of these Utah counties (1970-1975) with 5 additional years of data and found no excess among males. Creagan (1974) in an ecological study considered deaths in 23 coal counties from 1950-1969 and found elevated SMR's for males and females. Higgins (1977) in a nine-year follow-up of two West Virginia communities found a slight excess. Cochrane (1979) also found a slight excess but no consistent relationship with pneumoconiosis category. Ames (1982c) has shown that the risk of gastric cancer from coal mine dust exposure was statistically significant for long term smokers.

A summary of the status of the role of coal mining and various diseases is given below. These observations are made by assuming that an excess in mortality exists if a SMR is significantly greater than 100, and a deficit exists if less than 100. One might argue that SMR's between 80-100 for all causes, lung cancer, and pneumoconiosis category may be significant due to the 'healthy worker effect'. From Redmond's results, this effect is unlikely to affect the lung cancer rates, but may play a role in the other two diseases. Since this effect cannot be substantiated, we should, however, acknowledge the possibility that the SMR range of 80-100 should be regarded with caution.

Summary of Literature on Coal Miner Mortality

1. All Causes

   . British and U.S. data conflict:

   - Most British studies showed slight excess mortality from all causes; Liddell and Heasman found no excess after considering errors in reporting occupation.
   - U.S.: Excess associated with anthracite but not bituminous coal mine dust exposure. However, results are conflicting.

2. Chronic Bronchitis

   . Excess generally shown by follow-up studies for risk of death from all causes given bronchitis at beginning of study.

3. Nonmalignant Respiratory Disease

   . All studies showed excess.

4. All Cancers

   . All studies but that of Enterline showed deficit.

5. Lung Cancer

   . Enterline's cross-sectional study showed a marked excess.
   . Most studies (British and U.S.) show range of SMR's to be low (29-91).
   . By pneumoconiosis category at beginning of follow-up period:

   - Only necropsy studies show excess for category 0 and category 1-3.
   - Goldman and Cochrane (1979) showed a decrease in SMR from category 0 to categories 1-3, and an increase from category 1-3 to PMF. However, studies have reported deficit mortality regardless of x-ray category, including deficits in lung cancer mortality among those with PMF.
   - Few studies have controlled for potential risk factors.

6. Stomach Cancer

   . Conflicting results: Excess mortality is a possibility.

7. Pneumoconiosis

   . Mortality similar between category 0 and 1-3.
   . All but Carpenter showed that mortality increased among those with PMF. Ortmeyer showed this among smokers and those with airways obstruction.

METHODOLOGY

The Appalachian Coal Miner Study (1963-1965)

Between January 15, 1963 and January 15, 1965, 2549 working miners and 1177 ex-miners who were identified in 1962 were examined as part of the U.S. Public Health Service's cross-sectional survey of Appalachian bituminous coal miners. The study spanned seven states (Pennsylvania, Ohio, West Virginia, Kentucky, Virginia, Tennessee, and Alabama), and mines and miners were selected in a two-stage random selection where selection probabilities were proportional to mine size. Each working miner sampled represented 40 in the population and each mine represented 25 mines. The ex-miners differed from the miner population in that they were not employed in coal mining, were limited to ages 35 to 65, and were selected from the files of the United Mine Workers of America Union. Details of the study were given by Lainhart (1969).

Each person in the study received a limited medical examination consisting of a standard PA chest radiograph and test of spirometry, and was asked to answer questions concerning respiratory symptoms and his occupational and smoking history (Appendix A). The chest radiographs were classified by three physicians according to the U.S. Public Health Service's modified version of the ILO classification (Lainhart, 1969). Spirometry maneuvers were recorded following one practice blow on a wedge model 170 spirometer. A list of data on file is shown in Table 2.

During the analysis, the responses to questions concerning cough, phlegm, dyspnea, and chronic bronchitis were defined as follows:

Cough

None - No cough most days or nights.

Mild - Cough each day, but less than 3 months/year.

Severe - Cough each day for at least 3 months/year.

Phlegm

None - No phlegm most days or nights.

Mild - Phlegm each day, but less than 3 months/year.

Severe - Phlegm each day for at least 3 months/year.

Chronic Bronchitis

Mild cough and severe phlegm or severe phlegm regardless of cough.

Dyspnea

Breathlessness when hurrying on the level ground or walking up a slight hill, when walking with other people of the same age on level ground, when walking on level ground at own speed, or when washing or dressing.

Mortality Follow-up (1963-1975)

Ortmeyer (1974) conducted a 10-year mortality follow-up of this sample as of January 1, 1972. At that time, the follow-up of the vital status of the original cohort was 99% complete. A person was defined as living at the end of the follow-up period if, after 1972 an income tax return had been filed with the Internal Revenue Service (IRS), social security tax had been paid, death was not established, or a current address was obtained combined with no report of death from state death indexes, beneficiary or death claim files. A miner was determined deceased if reported so on a death certificate found through a claim for benefits or termination of benefits as a result of death. Using these criteria, the original cohort was again followed through 1975 and the causes of death were coded by the Eighth Revision of the ICDA (U.S. Dept. HEW, 1968).

Statistical Methods

Three methods were used to assess mortality trends. First, the life table regression method suggested by Cox (1972) was employed to test for differences in survival trends over time among subgroups. A list of all factors considered and their value or units in the model is shown in Table 3. Second, survival probabilities over time were calculated by the method of Kaplan and Meir (1958) and provided a graphical view of observed mortality trends. Finally, Standardized Mortality Ratios (SMR's) were calculated to compare the mortality among the study cohort to that of the U.S. white male population, using the modified life table approach described by Monson (1974) and NIOSH's life table analysis system program (NIOSH, 1980).

Differences between survival patterns can be estimated by the regression technique; i.e., differences between x-ray categories, smoking habits, mining groups, and levels of other factors. However, the regression results did not determine whether risks exceeded those of an 'unexposed' population. These data are provided by the SMR.

Cox's method provides a model for the conditional probability of dying ($\lambda(t, z_1, z_2, z_3 \ldots z_k)$) by time (t) since entry into the study assuming an individual was exposed to factors z_1, ..., z_k (e.g., age, race, smoking, ..., (see Table 3)). The model is then written as:

$$\lambda(t, z_1, z_2, \ldots z_k) = \lambda_o(t) \exp (B_1 z_1 + B_2 Z_z + \ldots + B_k Z_k)$$

where the B_i are the regression coefficients and $\lambda_o(t)$ is the underlying conditional probability at the zero level of each B_i. The coefficients were estimated by maximizing the 'likelihood of the sample' (Cox, 1972) with a computer program written by Harrell (1980).

Models were derived for death from all causes, ischemic heart disease, nonmalignant respiratory disease, lung cancer, digestive cancer, and accidents using a 'stepwise procedure' and the following strategy:

(1) Age, x-ray category (X1 and X2), and smoking (S1 and S2) were forced to remain in the model. The remainder of the variables were added only if Cox's Q statistic was significant at the 5% level. Lee (1980) showed this statistic to be comparable to the chi-square from the likelihood ratio test.

(2) Cross product terms (interactions) between age, years underground, x-ray category, and smoking status were similarly evaluated after forcing the significant terms in step (1) to remain in the model.

RESULTS

Of the 3726 miners and ex-miners in the original cohort, 3701 (99%) had their vital status verified at the end of or during the follow-up period (see chart, page 12a). Eight individuals were lost to follow-up but were living during the follow-up period; 843 died (death certificates were obtained for 782), and 2850 were living at the end of the follow-up period.

Of the 3701, 3340 (89.6% of the 3726) had administered to them an occupational history, respiratory questionnaire, and an acceptable postero-anterior chest radiograph. Finally of the 3340, 3151 (84.5% of the 3726) had a spirometry test. The distribution of baseline exposure variables, anthropometric variables, radiographic findings, and respiratory symptoms were compared

STATUS OF FOLLOW-UP

3726
Initial Cohort → 25 lost to follow-up

3701
(99%)

2850 living on December 31, 1975

843 died before January 1, 1976 (date of death recorded)

8 lost to follow-up but found living during study period.(paid into Social Security fund)

782 (93%) death certificates obtained

51 death certificates not obtained. Date of death from SSA.

787 with cause of death recorded.

5 without cause of death recorded.

among these cohorts (Table 4). Similar distributions were found which suggest that results from the regression analysis using the complete file of 3151 should be comparable to an SMR analyses using the file of 3701.

Table 5 lists the specific causes of death considered in this report and their ICDA Eighth Revision codes, and Table 6 shows the proportional mortality from selected causes. As expected, ischemic heart disease claimed the greatest proportion of deaths, followed by cancer and then nonmalignant respiratory disease.

Regression results are shown in Table 7. All variables listed in the table were considered during the stepwise procedure. In addition, urban/rural place and geographic region of residence, bronchitis, cough, phlegm, and years worked underground in a coal mine were also considered, but are not listed in the table because they were not found to be significant in any model.

Standardized Mortality Ratios (SMR's) were calculated for specific causes and are shown in Table 8 for the total cohort of 3701. Excess deaths were observed from nonmalignant respiratory diseases other than influenza, bronchitis, pneumonia; and from accidents. Excesses were suggested from cancer of the larynx, chronic rheumatic heart disease, influenza, bronchitis, cancer of the biliary passages and liver, and cancer of the peritoneum; however, these data are weak due to small expected number of deaths.

The number of individuals at risk at the beginning of the study period are listed in Table 9 for various subgroups. SMR's were calculated for each cell when expected numbers of death were greater than 1.

All Causes

The regression model (Table 7) showed that death from all causes was related to age, PMF, current smoking, mining status, pack years, dyspnea, and forced expiratory volume in one second (FEV_1). Chronic bronchitis, dyspnea, height, weight, and other dusty exposures were not found significant, and survival was similar between non and ex-smokers, and between categories 0 and 1-3. The relative contribution of the factors in the model are compared below by multiplying their value in the model by their regression coefficients.

VARIABLE	VALUE	REGRESSION COEFFICIENTS x VALUE OF VARIABLE
Age	20 years	1.24
	50 years	3.09
PMF	1	.42
Current Smoking	1	.45
Ex-mining Status	1	.19
Dyspnea	1	.25
FEV_1	3.0 liters	- .82
	2.0 liters	- .54
Pack Years	20.0 (packs/day)·years	.12
	40.0 (packs/day)·years	.24

Clearly, age is the most significant factor, followed by FEV_1, PMF, current smoking, pack years, dyspnea, and mining status. When S1 and S2 were excluded from the model, PMF was equivalent to 40 pack years of smoking.

Survival probabilities were calculated by time since entry into the study using the method of Kaplan and Meir (1958). Figure 1 shows results by x-ray category and smoking status which are consistent with the model, although these paterns are not age-adjusted. Survival curves for ex- and current smokers with PMF were the lowest of all subgroups, and curves for nonsmoking PMF's and current smokers with category 0 were similar.

Pack years of smoking was categorized into 0, 1-19, 20-39, and 40+. Figure 2 suggests that survival among ex-miners declined linearly with pack years and markedly decreased after 40. Figure 3 shows that ex-miners with category 0 who smoked 40+ pack years had a survival pattern similar to those with PMF who smoked 20 pack years or more. Similar trends were noted for miners. Although the model indicated that the contribution of pack years is linear, the graphical results suggest a threshold of 20 pack years among those with PMF and 40 among those with category 0.

The results of the SMR analysis is shown in Table 10. The SMR was slight for the overall group (110.4), ex-miners (125.6), miners (96.4), those with greater than 30 years underground (115.7), and those with less than 30 years underground (103.7). Among miners, risks were not significant regardless of tenure, and among ex-miners, the SMR's were similar but only slightly elevated among the two categories of years worked underground (122.4 and 125.5).

When stratifying by x-ray category, a significant excess of deaths from all causes was only found among working miners with PMF who either smoked, worked greater than 30 years underground, or had an $FEV_1/FVC\%$ greater than 70. Ex-miners with PMF had an elevated SMR regardless of other risk factors. Categories 0 and 1-3 were only associated with a marked excess when coupled with current smoking, dyspnea, obstruction, or bronchitis. No excesses were found for miners or ex-miners who were neither smokers nor had airways obstruction. The SMR also showed results for pack years consistent with Figure 1.

Ischemic Heart Disease

The regression analysis suggested that mortality from IHD was associated with age, mining status, other dusty exposures, pack years, dypsnea, FEV_1, and weight. Kaplan-Meir survival patterns tended to be lower among current smokers with category 1-3 although differences were not marked (Figure 4). A similar excess risk for this subgroup was suggested by the SMR (Table 11).

SMR's were generally low for miners and excess mortality was only shown for current smokers with category 1-3 (174.9) and for those with bronchitis and category 1-3 (271.9). Ex-miners had an increased risk of death but only when associated with smoking, obstruction, bronchitis, dyspnea, or other dusty exposure. Neither years underground nor x-ray category was associated with death from IHD. It is difficult to conclude from these data that coal mine dust exposure is responsible for increasing the risk of IHD; however, due to the results for smokers with category 1-3, a dust/smoking interaction cannot be ruled out.

Nonmalignant Respiratory Disease (NMRD)

Death from nonmalignant respiratory diseases was related to age, x-ray category, smoking, mining status, pack years, FEV_1/FVC%, FVC, height, and weight (Table 7). FEV_1/FVC% was the predominant explanatory factor followed by age and PMF. An interaction was suggested between smoking and x-ray category and is illustrated in Figure 5. Survival trends were similar for ex- and current smokers which were lower than those for nonsmokers. This was true for category 0 and PMF; however, for those with category 1-3, ex-smokers had much lower survival probabilities than did current smokers. These tentative findings could be due to a selection bias, but a synergism should not be ruled out.

The effect of PMF was equivalent to 83 pack years (the ratio of the regression coefficients) which can be interpreted as 2 packs/day for 41.5

years. Survival patterns (Figure 6) for ex-miners were markedly separated for those who smoked 0, less than 19, and greater than 20 pack years. Similar results were observed among those with each x-ray category.

Table 12 shows the SMR's for death from nonmalignant respiratory disease other than influenza, bronchitis, and pneumonia. Risks were markedly elevated for the total group (218.6) and for ex-miners (311.0), but not among miners (109.5). Among miners, excess mortality was only found associated with airways obstruction (200.1) and other dusty exposures (127.3). Among ex-miners, SMR's linearly increased with x-ray category, smoking habit, pack years, years underground, $FEV_1/FVC\%$, bronchitis, dyspnea, and other dusty exposures. A deficit number of deaths was found for nonsmokers and for those without airways obstruction regardless of mining group. The numbers at risk were too small to calculate SMR's for nonsmokers by x-ray category.

Lung Cancer

Results from the life table regression model suggested that lung cancer mortality was associated with age, x-ray category, smoking, and mining group. The effect of PMF was less than that of smoking and both were less than that of age. Neither years underground, pack years, lung function, nor weight contributed to the model once age, x-ray category, smoking, and miner status were included.

The Kaplan-Meir survival probabilities were helpful in interpreting these data (Figure 7). The results showed that no deaths from lung cancer occurred among PMF nonsmokers and only 1 among PMF ex-smokers, likely due to small numbers at risk. These results were in marked contrast to the decreased probabilities of PMF smokers. Among smokers, patterns were markedly different among those with category 0, 1-3, and PMF, and these results were found for both miners and ex-miners.

SMR's for lung cancer are presented in Table 13. The risk was generally low; 86.0 for the total group, 91.8 for miners, and 79.4 for ex-miners. An excess number of deaths was only shown among smokers, particularly above 20 pack years, although risks were only statistically significant for miners who smoked more than 40 pack years.

SMR's were elevated for x-ray category 1-3 only among smokers. Overall the SMR was 62.4 for category 0, 182.2 for category 1-3, and 217.1 for PMF. When miners and ex-miners were considered separately, only smokers with x-ray category 1-3 had elevated risks (322.9 and 474.3 respectively). The data were insufficient to estimate the SMR among PMF's for most groups.

Digestive Cancer

Among all factors considered, only age was found to contribute significantly to the probability of death from a digestive cancer. The SMR was not significantly greater than 100 in any subgroup (Table 14), and was 68.3 overall, 61.3 for miners, and 75.3 for ex-miners. Current smokers had a risk of 100.2. Neither radiographic category of pneumoconiosis, years worked underground in a coal mine, smoking, nor $FEV_1/FVC\%$ were related to an increased risk of death from digestive cancer.

Accidents

Regression coefficients are not shown in Table 7, however, the results showed that miners were at a greater risk of death from accidents than ex-miners. This was also supported by the SMR results (Table 15). SMR's for miners were consistently around 200 except among those with dyspnea (106.3) and those with greater than 1 year of other dusty exposures (84.0). SMR's for ex-miners varied among subgroups and was 110.8 overall.

DISCUSSION

The results after 14 years of follow-up were similar to those published by Ortmeyer (1974) and Costello (1974, 1975) after 10 years of follow-up. A summary is presented in Table 16.

FEV_1 and age were the predominant factors in the model for death from all causes, while PMF and smoking had a similar contribution. Mortality from all causes, IHD, and lung cancer was excessive among those who smoked more than 20 pack years while the risk of death from NMRD was elevated even among those who smoked 1-19 pack years.

Coal mine dust exposure measured by years-worked underground and x-ray category was not associated with death from IHD, digestive cancer, or accidents, but PMF significantly increased the risk of death from all causes and NMRD. Those with categories 0-3 and those who had never smoked regardless of mining group did not experience an excess mortality from all causes or NMRD. These results may suggest a statistical interaction between coal mine dust exposure and cigarette smoking in the etiology of several diseases.

It is premature, however, to conclude that coal mine dust does not increase the risk of dying from a NMRD among nonsmokers. The regression model suggested that survival patterns were similar for nonsmokers with categories 0-3 but were higher than those for nonsmokers with PMF, but the SMR could not be calculated since the number at risk with category 1-3 and PMF were small. Thus, we cannot conclude that the risks exceed those from a 'nonexposed' populaton. A more suitable blue collar control group will be sought to estimate more precisely these effects.

Ortmeyer (1974) showed after 10 years of follow-up of this study cohort that bronchitis was associated with premature death and the SMR results from this study were consistent with these findings. However, bronchitis was not found to be a significant factor in the regression model after age, smoking, mining status, and x-ray category was included. Since the data were not sufficient to control for smoking by the SMR method, this might explain the differences in results.

The most noteworthy result was the statistical association between lung cancer and x-ray category among smokers which is inconsistent with findings from previous studies of coal miners. Cochrane (1980a, 1980b) in his 20-year follow-up of the Stavely and Rhonda Fach cohorts reported low SMR's and no trend with x-ray category. However, Ames (1982c) found coal mine dust exposure to increase the risk of lung cancer among smokers (although not statistically significant) and among those with impaired lung function in a case-control study which used cases from this cohort and three other U.S. coal mine samples.

Several possible explanations for the results are discussed: (1) small numbers at risk; (2) selection bias; (3) confounding from other risk factors; and (4) misclassification of disease.

Small numbers at risk generally prohibit detecting excess mortality for a disease with a long latency or a low incidence. Excess mortality was found for smokers with category 1-3 and PMF, an association not likely affected by the sample size. However, the deficit mortality among non and ex-smokers with category 0, 1-3, and PMF may reflect an inadequate sample size with respect to a low probability of death from lung cancer. In addition, 14 years of follow-up may not be sufficient to detect lung cancer in these low risk groups with respect to their age.

Selection bias could not entirely explain the results. An out-migration of smokers with a low risk of lung cancer in greater proportion with increasing x-ray category could explain the results but the findings were similar among miners and ex-miners. In fact, the reverse would be expected. Current or ex-smokers may have changed their smoking habits in the first few years of follow-up, but then they would have had similar survival patterns which were not found.

Certainly confounding from other risk factors for lung cancer has not been ruled out. More data need to be collected on risk factors such as genetics, ethnicity, migration from an area with a high or low prevalence, socio-economic status, and occupational exposure to suspected carcinogens before the coal mine dust/lung cancer association can be substantiated (Waxweiller, 1978).

The cause of death was not likely misclassified differently among those with different x-ray categories. If there were a misclassification bias, those with pneumoconiosis who died would probably have had their cause of death listed as NMRD more frequently than those without CWP, and then lung cancer (if present) would likely have been a contributing cause. Further analyses of the contributing causes of death is planned, but will probably not change the results. Furthermore, James (1955) reported that the percentages of false positive and negative indications of lung cancer from death certificates were similar and quite low. Further study is recommended as follows:

(1) Environmental exposure data on a U.S. coal miner cohort is needed to define more precisely the dose-response relationship between coal mine dust exposure and death from all causes, NMRD, and lung cancer.

(2) A larger number of nonsmokers with coalworkers' pneumoconiosis needs to be obtained to separate the effects of smoking from coal mine dust exposure.

(3) A more suitable blue collar control group is needed rather than the U.S. population.

(4) This cohort should be followed for at least 5-10 more years to determine if there is any excess mortality from lung cancer among the low risk groups after sufficient time is allowed for a long latency.

(5) More data on risk factors for lung cancer should be obtained.

Further work is planned:

A case-control study is now in progress in which lung cancer cases were selected from the study cohort, from a cohort of miners who filed for disability with the state of West Virginia (Charleston-Beckley cohort), from a cohort of miners examined in the first round of the National Study of Coalworkers' Pneumoconiosis (Morgan, 1972), and from the National Coalworkers Autopsy Study (Ames, 1982b). Finally, due to the provocative results concerning the association between lung cancer risk and coal mine dust exposure, these data are being analyzed in more detail and will be forwarded to the director, NIOSH when they are prepared for a journal publication.

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STANDARDIZED MORTALITY RATIOS FOR MALE COAL MINERS

TABLE 1

AUTHOR (DATE)	DATA TYPE	YEAR OF DATA	MINERS	CONTROLS	ALL CAUSES	NON-MALIGNANT RESPIRATORY	LUNG CANCER	STOMACH CANCER
Kennaway (1937)	D/C	21-32	England & Wales	General population England & Wales			59	
	D/C	33-38	"	"			59	
______ (1947)					Pneumoconiosis:	Slight =	177	
James (1958)	Necropsy	47-52	South Wales	Population South Wales		Moderate = Severe = PMF =	121 122 42	
Doll (1958)	D/C	48-53	"	"			48	
Carpenter (1956)	D/C	50-53	Rhonda Fach	England & Wales 50-53	122.9			
Cochrane (1964)	6 yr cohort	51-56	"	"	143.4			
Goldman (1965)	"		"	"			81.1	
______ (1965)	D/C National Coal Board	55	England & Wales	"			70.1 91.5	
					ALL / F / S			
Heasman (1958)	D/C	49-53	"	"	112 / 148 / 107			
	Census	55	"	"	117 / 142 / 109			
	National Coal Board	55	"	"	100 / 81 / 135			
Stocks (1962)	D/C	49-53		49-53	Miners: 135 Wives: 175			149 154
Enterline (1964)	D/C	50	United States (age 20-64)	U.S. Males with work experience 1950	195	491	192	275
Higgins (1968)	9 yr cohort	57-66	Stavely England	England & Wales	% DEAD AGE: 25-34 / 55-64 Non-dusty 0 / 22.2 Coal 1.1 / 21.5 All 1.6 / 24.8			

TABLE 1

AUTHOR (DATE)	DATA TYPE	YEAR OF DATA	MINERS	CONTROLS	ALL CAUSES	NON-MALIGNANT RESPIRATORY	LUNG CANCER	STOMACH CANCER
Enterline (1972)	Actuary	49-63	Policyholders Underground miners	Policyholders Standard Risk	172	1111	260	
(1972)	28½ year cohort	37-66	533 miners - West Virginia	U.S. Males	158	150	111	210[1]
Liddell (1973)	D/C	60	England & Wales	Occupied and retired males 59-63	F: 77 U: 102 S: 137		49 53 82	101 128 32
Ortmeyer (1973)	5 yr cohort	65-71	Receiving compensation for black lung in PA 65-57	PA white males 59-61	Anthracite: 127 Bituminous: 100			
Costello (1974,75)	10 yr cohort	62-71	3726 U.S. Appalachian	U.S. Males			67	
Ortmeyer (1974)	"	"	"	"	104			
Rockette (1977)	12 yr cohort	59-71	UMWA file	U.S. Males 59-71: U.S. Males 65:	102 101	157	113[2] 114[2]	97[1] 98[1] 138
Matalo (1972)	Utah tumor registry; census	65-69	-2 Utah mining counties -Total Co Pop.	-Utah county (nonmining) -Utah population			COUNTY MALE Emery 338 Carbon 342 Utah 77	FEMALE 152 229 93
Creagan (1974)	D/C	50-69	23 U.S. coal counties	Non-coal counties		MALE: FEMALE:	130 110	130 120
(1973)	D/C	63-69	6 Kentucky counties	U.S. population				
Klauber (1977)	Utah tumor registry	70-75	2 mining counties	-Utah county -Utah population			COUNTY MALE Emery 110 Carbon 92 Utah 83	FEMALE 32 200 .87

TABLE 1

AUTHOR (DATE)	DATA TYPE	YEAR OF DATA	MINERS	CONTROLS	ALL CAUSES	NON-MALIGNANT RESPIRATORY	LUNG CANCER	STOMACH CANCER
Rooke (1979)	Necropsy D/C	74-76	England & Wales	England and Wales			117	
Cochrane (1979)	20 year cohort	50-70	Rhonda Fach	England and Wales	Nonminers = Miners: Cat 0 = Cat 1-3 = PMF =	62 121 119 136	66 70 68 80	113 160 108 184
Higgins (1979)	8 yr cohort	63-71	2 West Virginia communities	U.S. Males	Richwood,WV: 128 Mullens: 135	244 292		
Cochrane (1980)	20 yr cohort	57-77	Stavely, ENGL Ages 25-34	England & Wales	% DIED % Non-dusty 3.5 Coal: 4.3 Foundry: 4.4 Other: 11.4			
(1980)			Stavely, ENGL Ages 55-64	England & Wales	Non-dusty: 71.3 Coal: 65.8 Foundry: 70.8 Other: 71.7			

TABLE 1

D/C - Death Certificate, cross-sectional study

U - Underground
S - Surface
F - Face

(1) Death from digestive cancer
(2) Death from cancer of respiratory system

TABLE 2

APPALACHIAN COAL MINER STUDY:
DATA IN COMPUTER FILE WHICH WERE OBTAINED AT EXAM
AND IN MORTALITY FOLLOW-UP FROM 1963-1975.

1. Race, sex, age, date of birth, height, weight
2. Last occupation
3. Years worked underground, at face, surface, and in mining
4. Years worked in other dusty jobs
5. Smoking status, pack years (cigarettes/day x number years smoked)
6. Pulmonary function: FEV_1, FVC, and % predicted
7. Symptoms: Dyspnea, cough, phlegm, chest illness
8. Past exposure to gases or fumes
9. X-ray category of pneumoconiosis (ILO classification) - a concensus of three readers
10. Occupational history
11. Deaths: date of death, state of death, underlying cause of death (Eighth Revision), all other causes listed (2 through 6)
12. Address in 1963 up to last four addresses reported during follow-up.

TABLE 3

VARIABLES CONSIDERED BY REGRESSION MODELS

DESCRIPTION	MODEL NOTATION	CODED VALUE IF CATEGORIZED OR UNITS IF CONTINUOUS
1. Age	age	Years
2. X-ray Category*	X1 X2	1 if x-ray category=1-3; 0 otherwise 1 if PMF; 0 otherwise
3. Smoking*	S1 S2	1 if current smoker; 0 otherwise 1 if ex-smoker; 0 otherwise
4. Mining Status	Mine	0 if miner; 1 if ex-miner
5. Other dusty exposures	Other	Years
6. Years worked underground in a coal mine	Under	Years
7. Pack years of smoking	Pk yrs	(Packs/day) * years smoked
8. Dyspnea		0 = No 1 = Yes
9. Cough		0 = none or mild 1 = severe
10. Phlegm		0 = none or mild 1 = severe
11. Chronic bronchitis		0 = No 1 = Yes
12. FEV_1		liters
13. FVC		liters
14. $(FEV_1/FVC)\%$		%
15. Height		cm
16. Weight		kg
17. Obstruction	Obs	0 if $(FEV_1/FVC)\% > 70\%$
18. Place of Residence		1 if population $\geq 50{,}000$; 0 otherwise
19. Area of Residence		1 if living in WV or PA; 0 otherwise

*X-ray category and smoking status are defined by two variables; e.g.,

Category 0: X1 =0 and X2 = 0

Category 1-3: X1 =1 and X2 = 0

PMF : X1 =0 and X2 = 1

TABLE 4

THE DISTRIBUTION (%) OF VARIABLES BY MINING STATUS
AMONG ALL WORKERS AND THOSE WITH COMPLETE DATA

	TOTAL GROUP		MINERS		EX-MINERS	
	#1*	#2*	#1	#2	#1	#2
MINING STATUS						
Miner	68.5	71.4				
Ex-Miner	31.5	28.6				
AGE						
<19	0.2	0.1	0.2	0.2	-	-
20-24	0.9	1.0	1.4	1.3	-	-
25-29	2.5	2.6	3.6	3.6	-	-
30-34	4.7	4.7	6.7	6.5	0.3	0.2
35-39	9.0	9.3	11.9	12.0	2.5	2.4
40-44	13.3	13.7	17.6	17.6	4.0	3.8
45-49	15.9	16.2	20.0	20.1	6.9	6.6
50-54	15.6	16.2	18.6	19.1	9.2	8.9
55-59	15.2	15.2	13.1	13.0	20.1	20.7
60-64	21.4	20.0	6.5	6.1	53.8	54.8
65-69	1.1	0.9	0.2	0.2	3.1	2.7
70-74	0.0	0.0	0.0	0.0	-	-
75+	0.0	0.0	0.0	0.0	-	-
RACE						
White	91.1	92.0	93.7	94.2	85.4	86.7
Non-white	8.4	7.8	5.9	5.6	13.7	13.3
Missing	0.5	0.1	0.3	0.2	0.9	-
PRINCIPLE JOB						
Face	44.7	47.1	44.0	43.3	52.7	56.9
Transportation	18.8	20.1	19.1	20.6	18.2	19.2
Maintenance	11.6	12.4	12.2	13.1	10.3	10.9
Miscellaneous	4.6	5.1	6.4	6.8	0.9	0.9
Surface	12.0	12.6	13.1	13.5	9.4	10.3
Other	2.4	2.5	2.8	2.8	1.7	1.8
Missing	5.9	-	5.5	-	6.9	-
SMOKING						
Never Smoked	21.0	20.8	19.5	19.6	24.3	23.9
Current Smoker	56.3	57.1	60.8	61.0	46.4	47.4
Ex-Smoker	22.0	22.1	19.2	19.5	28.0	28.6
Missing	0.7	-	0.5	-	1.2	-
X-RAY CATEGORY						
0	85.8	87.1	88.6	89.7	79.6	80.6
1-3	8.2	8.4	7.3	7.4	10.0	11.0
PMF	4.8	4.5	3.0	2.9	8.9	8.4
Missing	1.2	-	1.1	-	1.5	-

TABLE 4, continued

	TOTAL GROUP		MINERS		EX-MINERS	
	#1	#2	#1	#2	#1	#2
REGION						
W. Va. and Pa.	63.1	63.2	62.9	63.4	63.5	62.6
Other	36.9	36.8	37.1	36.6	36.5	37.4
AREA						
Urban	3.0	2.9	3.1	3.0	2.7	2.4
Rural	97.0	97.1	96.9	97.0	97.3	97.6
COUGH						
None	67.3	68.2	74.4	74.1	51.9	53.4
<3 mos, <3 yrs	6.0	6.3	5.8	6.1	6.3	6.9
<3 mos, >3 yrs	5.2	5.1	4.5	4.5	6.8	6.5
>3 mos, <3 yrs	14.3	13.6	9.3	9.3	25.1	24.6
>3 mos, >3 yrs	6.8	6.7	5.9	6.0	8.8	8.6
Missing	0.4	-	0.1	-	1.0	
PHLEGM						
None	73.0	74.2	79.7	79.8	58.6	60.2
<3 mos, <3 yrs	4.9	5.0	4.3	4.4	6.3	6.6
<3 mos, >3 yrs	4.7	4.6	4.1	4.1	5.9	6.0
>3 mos, <3 yrs	11.9	11.1	7.8	7.6	20.9	20.0
>3 mos, >3 yrs	5.0	5.0	3.9	4.0	7.3	7.2
Missing	0.4	-	0.1	-	1.0	-
CHRONIC BRONCHITIS						
No	77.0	78.3	83.3	83.4	63.4	65.4
Yes	22.6	21.7	16.6	16.6	35.6	34.6
Missing	0.4	-	0.1	-	1.0	-
DYSPNEA						
None	37.4	38.4	47.6	47.2	15.0	16.4
Mild	35.8	37.4	39.4	40.4	28.0	30.0
Severe	25.2	24.2	12.7	12.4	52.4	53.6
Disabled	1.2	-	0.2	-	3.5	-
Missing	0.4	-	0.1	-	1.0	-
AIRWAYS OBSTRUCTION						
No	59.3	64.0	67.3	70.6	42.0	48.6
Yes	33.3	36.0	28.2	29.4	44.3	52.4
Missing	7.4	-	4.5	-	13.6	-
DEATHS						
No	77.2	78.0	84.8	84.6	60.6	61.6
Yes	22.8	22.0	15.1	15.4	39.4	38.4
MEANS						
Age	49.8	49.5	46.1	46.1	57.8	58.0
Years worked underground	23.8	23.7	21.2	21.2	29.7	29.9
Years other dusty exposure	0.3	0.3	0.2	0.2	0.5	0.5
Pack Years	21.3	21.6	20.4	20.6	23.2	24.1
Height	174.9	174.9	175.5	175.4	173.7	173.7
Weight	76.8	76.9	77.6	77.7	74.9	75.0
FEV_1	2.9	2.9	3.1	3.1	2.4	2.4
FVC	4.0	4.0	4.2	4.2	3.5	3.5
$(FEV_1/FVC)\%$	71.8	71.8	73.7	73.7	67.1	66.8
Time +	3855	3875	4018.8	4013	3498.9	3529
NUMBER	3701	3151	2535	2251	1166	900

TABLE 4, continued

+ Time = time from entry into study to last observation in study period.

* #1 = Total cohort of 3701

#2 = Cohort of individuals with data on all variables in Table 3.

TABLE 5

EIGHTH REVISION ICDA CODES

DISEASE CATEGORY	CODES
All heart disease	390-458
Ischemic Heart Disease	410-413
All Neoplasms	140-239
All Respiratory Cancer	160-163
Cancer of lung, trachea, and bronchus	162-163
Digestive Cancer	150-159
Stomach Cancer	151
Nonmalignant Respiratory Disease	460-519
Influenza	470-474
Bronchitis	466, 490-491
Pneumonia	480-486
Accidents and Violence	800-866, 870-895, 900-904, 940-985

TABLE 6

PROPORTIONAL MORTALITY

	# OF DEATHS	% OF ALL DEATHS
All Cancer	124	15
Digestive Cancer	31	4
Trachea, Bronchus & Lung	49*	6
Ischemic heart disease	313	37
Nonmalignant Respiratory Disease	99	12
Pneumonia	15	2
Bronchitis	9	1
Other	61	7
Accidents and Violence	70	8
Total	843	100

* Only 1 death occurred from cancer of trachea (163).

TABLE 7

COEFFICIENTS IN REGRESSION MODELS +

	CAUSE OF DEATH				
VARIABLE	ANY CAUSE	ISCHEMIC HEART DISEASE	NONMALIGNANT RESPIRATORY DISEASE	LUNG CANCER	DIGESTIVE CANCER
AGE	.06178*	.06915*	.05832*	.13007*	.15222*
X1	.01567	.08670	-.11587	1.06951*	-.53581
X2	.41734*	-.22825	1.20027*	1.62463*	-.05699
S1	.44452*	.40048	.80771	2.93325*	.70265
S2	.01537	-.22868	.40680	1.49753*	.81221
MINE	.18948*	.45947*	.50927*	.85433*	-.14606
OTHER		.05425*			
PACK YEARS	.00594*	.00652*	.01445*		
DYSPNEA	.25243*	.34080*			
FEV_1	-.27200*	-.17035*			
FEV_1/FVC			-.04328*		
FVC			-.66221*		
HEIGHT			.05978*		
WEIGHT		.02008*	-.04327*		
X1 * S2			1.61792*		

* Cox's Q statistic was significant at the 5% level.

+ Age, X1, X2, S1, S2 and mine were included in all models.
See Table 3 for a description of the variables and their units or coded values.

TABLE 8

STANDARDIZED MORTALITY RATIOS (SMR's) FOR SPECIFIC CAUSES

AMONG 3701 MINERS AND EX-MINERS

	NUMBER OF DEATHS		
	OBSERVED	EXPECTED	SMR
(1) NEOPLASMS			
ALL DIGESTIVE	31	45.4	68.2
ESOPHAGUS	2	3.9	51.2
STOMACH	7	7.7	90.9
INTESTINE	5	14.6	34.2
RECTUM	3	5.1	58.8
BILIARY PASSAGES & LIVER	4	2.6	153.8
PANCREAS	9	9.4	95.7
PERITONEUM	1	.6	166.7
LARYNX	4	2.7	148.1
TRACHEA, BRONCHUS & LUNG	49	56.9	86.2
(2) ISCHEMIC HEART DISEASE	313	307.1	101.9
(3) NONMALIGNANT RESPIRATORY DISEASE			
INFLUENZA	3	1.1	272.7
PNEUMONIA	15	15.3	98.4
BRONCHITIS	9	3.6	250.0
OTHER	61	27.9	218.6
(4) ACCIDENTS	57	32.6	174.8
(5) VIOLENCE	13	15.3	84.9
(6) ALL DEATHS	843	763.3	110.4

TABLE 9

NUMBERS AT RISK AT THE BEGINNING OF THE FOLLOW-UP PERIOD

VARIABLES	TOTAL GROUP	MINERS X-RAY CATEGORY 0	MINERS X-RAY CATEGORY 1-3	MINERS X-RAY CATEGORY PMF	MINERS TOTAL	EX-MINERS X-RAY CATEGORY 0	EX-MINERS X-RAY CATEGORY 1-3	EX-MINERS X-RAY CATEGORY PMF	EX-MINERS TOTAL
YEARS UNDERGROUND									
≤30	2280	1684	84	30	1817	394	32	28	463
>30	1201	436	92	42	578	467	78	68	623
SMOKING STATUS									
NONSMOKER	778	433	38	20	494	224	32	24	284
CURRENT SMOKER	2083	1393	98	34	1542	441	57	33	541
EX-SMOKER	813	412	50	19	487	251	27	45	326
$FEV_1/FVC\%$									
≤70	2196	1550	112	34	1706	403	53	29	490
>70	1231	607	67	36	714	401	54	57	517
BRONCHITIS									
YES	837	368	41	13	422	321	42	44	415
NO	2850	1877	145	62	2111	596	74	60	739
DYSPNEA									
YES	934	257	43	20	323	464	62	78	611
NO	2708	1984	143	55	2206	421	50	24	502
OTHER DUSTY EXPOSURE									
0	3421	2112	176	73	2388	820	103	94	1033
≥1	265	133	9	2	144	97	13	10	121
PACK YEARS									
1-19	1065	722	40	19	792	216	27	27	273
20-39	645	431	28	8	474	133	24	11	171
40+	1149	632	78	26	741	330	32	39	408
TOTAL	3701	2247	186	75	2535	928	117	104	1166

TOTAL GROUP: X-RAY CATEGORY 0 = 3175

CATEGORY 1-3 = 3034

PMF = 179

TABLE 10

SMR'S FOR DEATH FROM ANY CAUSE

VARIABLES	TOTAL GROUP	MINERS X-RAY CATEGORY 0	1-3	PMF	TOTAL	EX-MINERS X-RAY CATEGORY 0	1-3	PMF	TOTAL
YEARS UNDERGROUND									
≤30	103.7	95.4	53.3	88.8	93.3	116.7*	116.1	207.7*	122.4*
≥30	115.7*	92.4	127.0	161.4*	102.1	123.8*	121.2*	159.0*	125.5*
SMOKING STATUS									
NONSMOKER	71.6*	60.1*	56.8	15.8*+	57.2*	84.2	74.3	115.0	84.0*
CURRENT SMOKER	144.6*	121.2*	142.6*	219.6*	125.4*	172.1*	150.2*	267.3*	173.1*
EX-SMOKER	86.3*	60.8*	57.1	182.6*	65.2*	95.4	101.9	151.7*	103.6
FEV_1/FVC%									
≤70	92.0	87.2*	97.4	68.6	87.8*	103.1	82.7	88.1	98.8
≥70	131.3*	113.9	96.3	213.2*	116.7*	138.4*	134.4	199.3*	143.1*
BRONCHITIS									
YES	151.6*	126.9*	157.0	156.1	131.8*	163.8*	148.4*	212.4*	164.0*
NO	97.0	87.8*	81.5	121.6	88.6*	105.1	99.2	150.7*	108.2
DYSPNEA									
YES	143.5*	132.3*	94.3	106.8	122.3*	149.9*	149.2*	177.6	151.1*
NO	93.7	88.7*	99.3	141.1	91.7	96.4	86.2	148.0	97.9
OTHER DUSTY EXPOSURE									
0	109.8*	96.3	89.6	119.8	96.6	124.2*	110.0	162.4*	125.1*
≥1	120.5	70.6	342.6*	-	95.1	119.7	147.6	344.5*	135.6*
PACK YEARS									
1-19	95.1	78.5*	36.8*	205.4*	79.1	109.6	97.5	166.7*	113.7
20-39	124.4*	116.5	135.5	151.5	118.1	126.7*	148.1	172.8	133.3*
40+	143.9*	117.8*	138.1	217.6*	123.3*	164.9*	158.3*	223.6*	168.0*
TOTAL	110.4*	94.8	97.6	128.9	96.6	122.5*	116.7	173.6*	125.6*

TOTAL GROUP: X-RAY CATEGORY 0 = 107.6*

CATEGORY 1-3 = 106.7

PMF = 157.8*

* Significant at 5% level.
\- Expected number less than 1.
\+ One observed death.

40c

FIGURE 1
KAPLAN-MEIR SURVIVAL PROBABILITIES OF DEATH FROM
ANY CAUSE BY X-RAY CATEGORY AND SMOKING HABIT

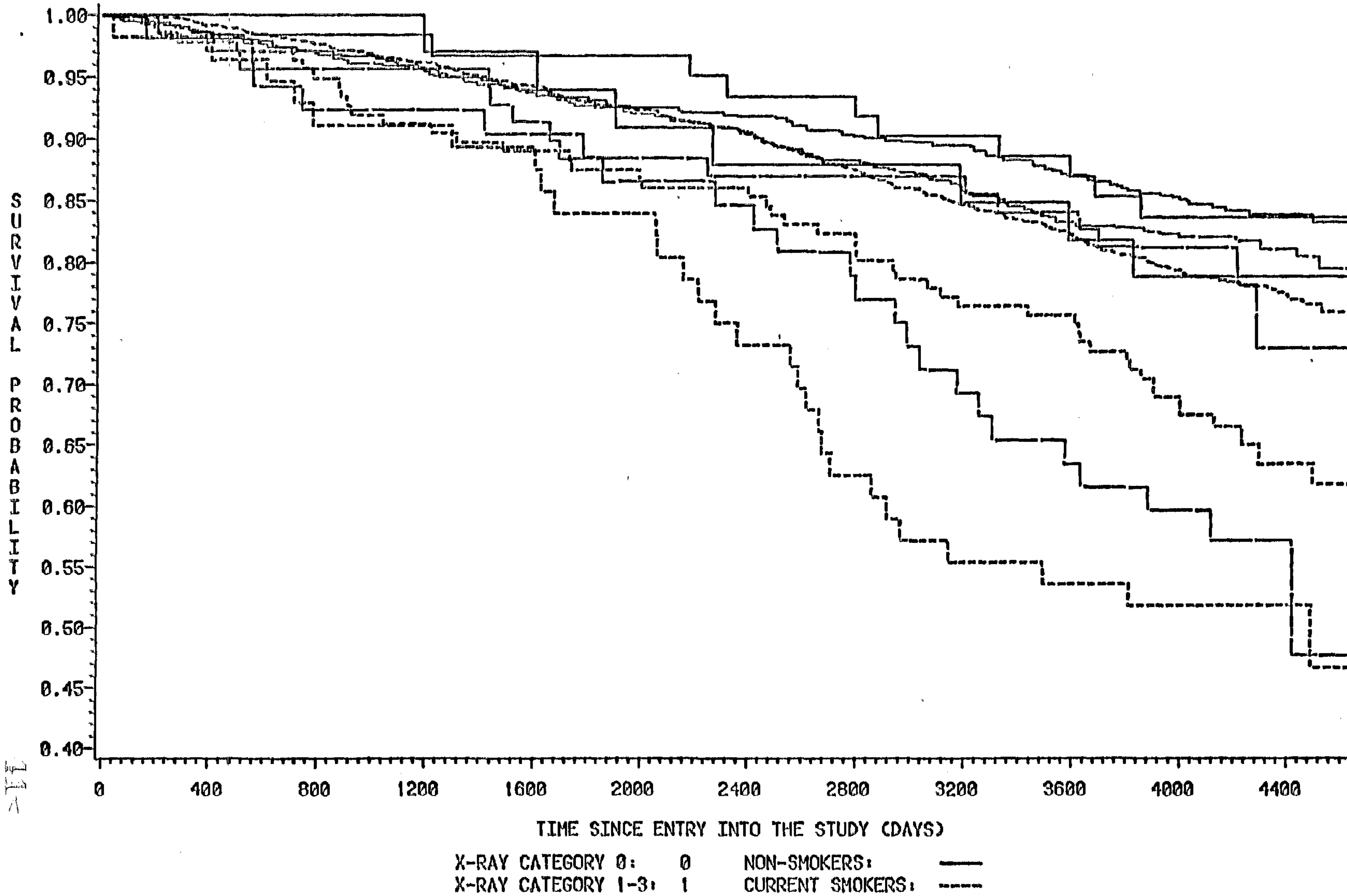


FIGURE 2
KAPLAN-MEIR SURVIVAL PROBABILITIES OF DEATH FROM ANY CAUSE BY PACK YEARS FOR EX-MINERS

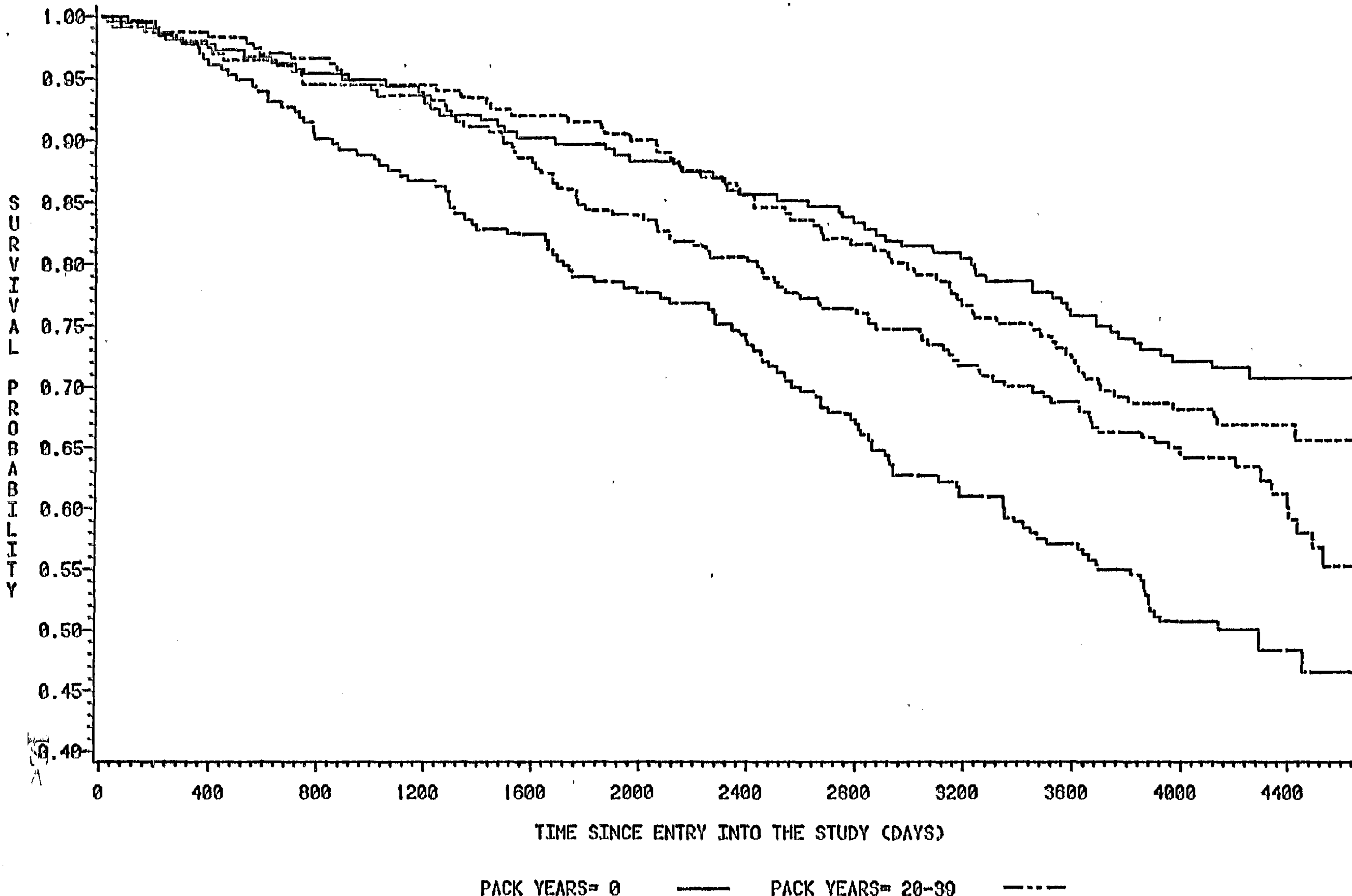


FIGURE 3

KAPLAN-MEIR SURVIVAL PROBABILITIES OF DEATH FROM ANY CAUSE BY X-RAY CATEGORY AND PACK YEARS FOR EX-MINERS

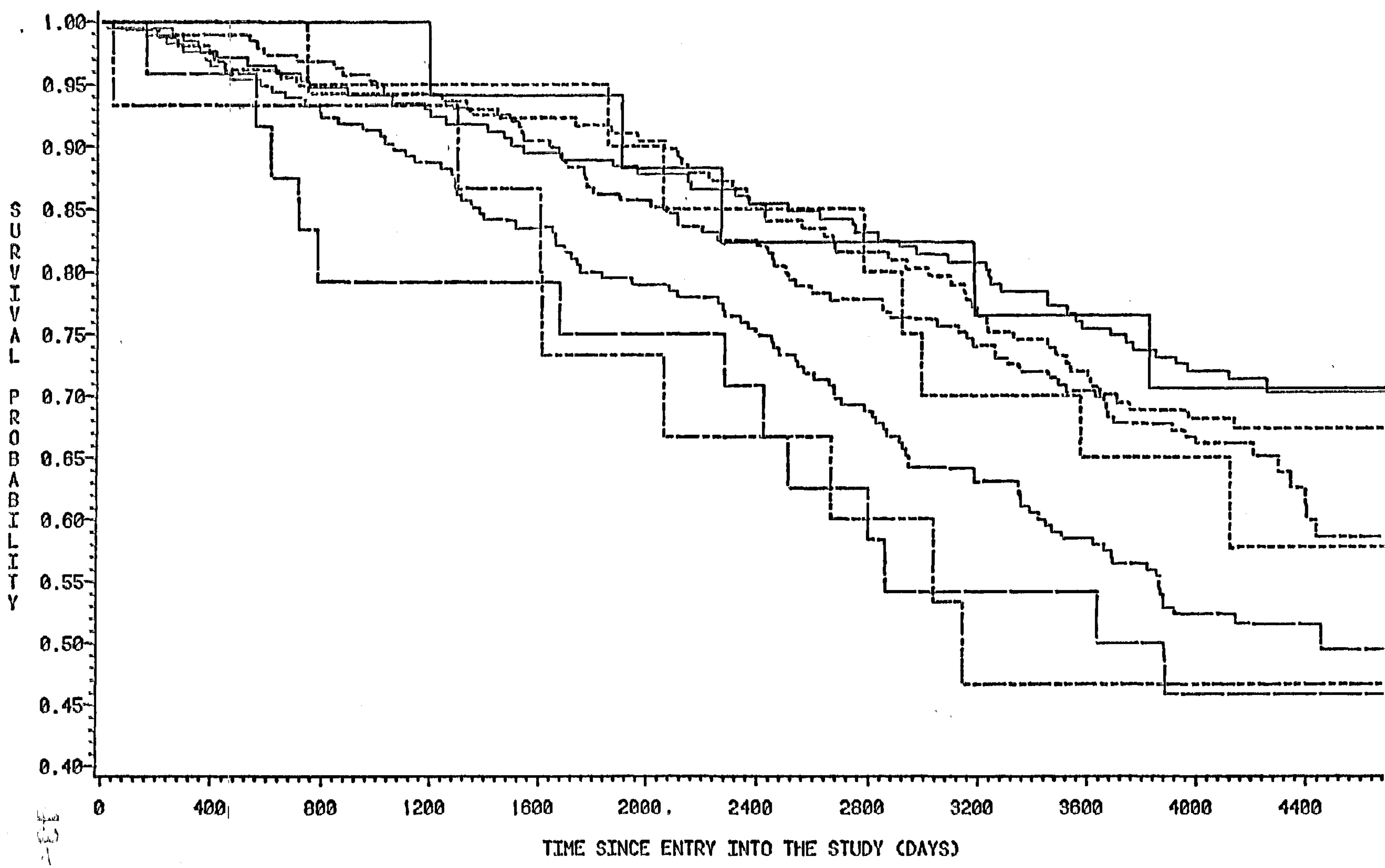


TABLE 11

SMR's FOR ISCHEMIC HEART DISEASE

VARIABLES	TOTAL GROUP	MINERS X-RAY CATEGORY 0	MINERS 1-3	MINERS PMF	MINERS TOTAL	EX-MINERS X-RAY CATEGORY 0	EX-MINERS 1-3	EX-MINERS PMF	EX-MINERS TOTAL
YEARS UNDERGROUND									
<30	105.5	92.9	38.1	54.8	90.4	140.4*	55.9	62.2	130.8*
>30	100.5	66.0*	144.3	43.2	77.6	123.6	124.1	76.7	116.7
SMOKING STATUS									
NONSMOKER	78.0*	55.1*	83.1	0	53.5*	105.0	99.2	55.1	98.3
CURRENT SMOKER	133.0*	105.3	174.8*	82.0	112.6	174.2*	111.4	106.9	161.7*
EX-SMOKER	69.1*	45.0*	19.8	54.5	41.4*	96.3	81.5	69.5	90.8
$FEV_1/FVC\%$									
<70	93.8	77.9*	108.9	33.3	81.1	124.6	106.4	21.2	113.1
>70	110.6	87.2	102.4	60.4	86.9	139.6*	94.5	98.9	128.9*
BRONCHITIS									
YES	125.5*	89.1	271.9*	0	107.4	150.6	119.0	78.6	136.3*
NO	94.5	79.7*	61.6	55.7	78.2*	122.1*	92.1	72.6	115.0
DYSPNEA									
YES	129.3*	125.1	91.4	42.5	111.1	152.0*	103.1	81.6	135.6*
NO	86.0*	74.2*	113.9	43.0	78.4*	102.4	90.9	59.1	100.3
OTHER DUSTY EXPOSURE									
0	99.6	80.5*	100.6	43.8	82.1	127.9*	107.8	72.0	119.0
>1	132.3	94.8	-	-	108.5	155.7*	50.2	-	145.7*
PACK YEARS									
1-19	77.5*	57.6*	30.1	70.7	57.4*	100.0	117.0	85.6	99.0
20-39	113.2	92.0	94.0	--	96.5	137.8	32.3	243.7	134.7
40+	131.6*	107.7	161.1	43.5	111.4	172.5*	142.4	43.0	154.6*
TOTAL	101.9	81.4*	108.0	42.8	83.6	130.0*	100.3	74.9	121.1*

TOTAL GROUP: X-RAY CATEGORY 0 = 104.4

CATEGORY 1-3 = 104.2

PMF = 63.8

* Significant at 5% level.

\- Expected number less than 1.

TABLE 12

SMR's FOR NONMALIGNANT RESPIRATORY DISEASE

VARIABLES	TOTAL GROUP	MINERS X-RAY CATEGORY 0	MINERS 1-3	MINERS PMF	MINERS TOTAL	EX-MINERS X-RAY CATEGORY 0	EX-MINERS 1-3	EX-MINERS PMF	EX-MINERS TOTAL
YEARS UNDERGROUND									
≤30	164.3*	72.7	-	-	82.3	170.0	-	-	266.6*
>30	273.0*	66.4	-	-	149.3	310.1*	431.9*	-	352.8*
SMOKING STATUS									
NONSMOKER	67.1	0	-	-	32.7	58.4	-	-	91.1
CURRENT SMOKER	304.9*	124.3	-	-	151.7	453.1*	-	-	477.1*
EX-SMOKER	230.4*	0	-	-	97.2	188.0	-	-	317.5*
FEV_1/FVC%									
<70	57.0	61.3	-	-	65.5	39.5	-	-	46.8
>70	342.4*	84.7	-	-	200.1*	392.3*	-	-	435.4*
BRONCHITIS									
YES	487.9*	157.5	-	-	208.9	518.9*	-	-	628.0*
NO	126.1	46.3	86.9	-	86.7	135.3	270.2	-	166.0*
DYSPNEA									
YES	419.4*	183.2	-	-	174.8	409.1*	-	-	494.3*
NO	113.8	45.1	93.7	-	95.7	119.5	-	-	140.4
OTHER DUSTY EXPOSURE									
0	205.4*	71.3	71.3	-	108.6	249.5*	356.1*	632.2*	292.3*
≥1	365.1*	-	-	-	127.3*	291.6*	-	-	476.9*
PACK YEARS									
1-19	239.9*	42.2	-	-	141.3	261.2*	-	-	321.6*
20-39	203.6*	118.1	-	-	102.8	266.1*	-	-	302.7*
40+	338.8*	104.0	-	-	147.2	426.3*	-	-	521.8*
TOTAL	218.6*	66.4	67.9+	-	109.5	252.4*	372.2*	814.2*	311.0*

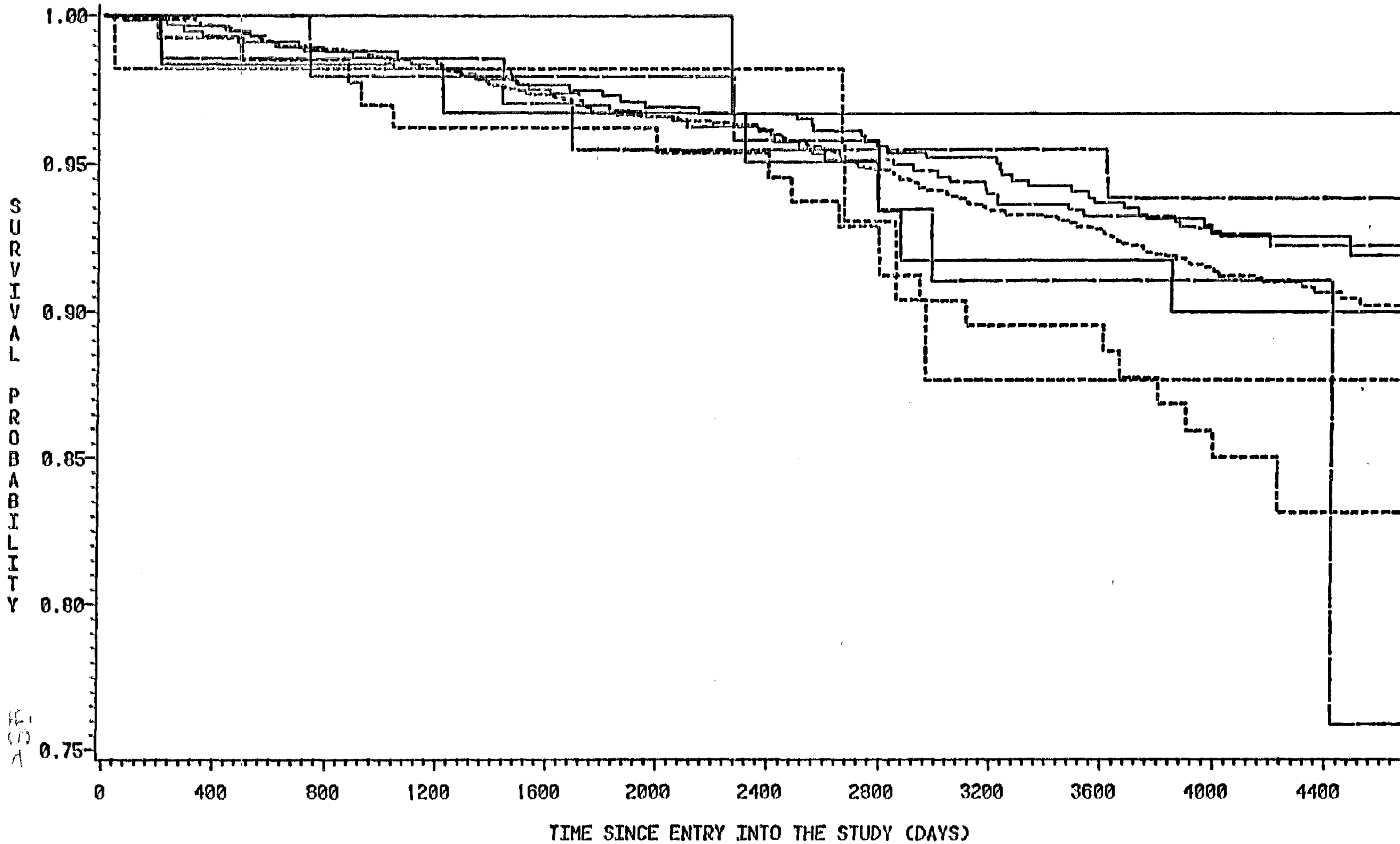
TOTAL GROUP: X-RAY CATEGORY 0 = 164.9*

CATEGORY 1-3 = 226.7*

PMF = 865.5*

* Significant at 5% level.
\- Expected number less than 1.
\+ One observed death.

FIGURE 4
KAPLAN-MEIR SURVIVAL PROBABILITIES OF DEATH FROM
ISCHEMIC HEART DISEASE BY X-RAY CATEGORY AND SMOKING



X-RAY CATEGORY 0: 0 NON-SMOKERS: ——
X-RAY CATEGORY 1-3: 1 CURRENT SMOKERS: ----

FIGURE 5
KAPLAN-MEIR SURVIVAL PROBABILITIES OF DEATH FROM
NON-MALIGNANT RESPIRATORY DISEASE BY X-RAY CATEGORY AND SMOKING

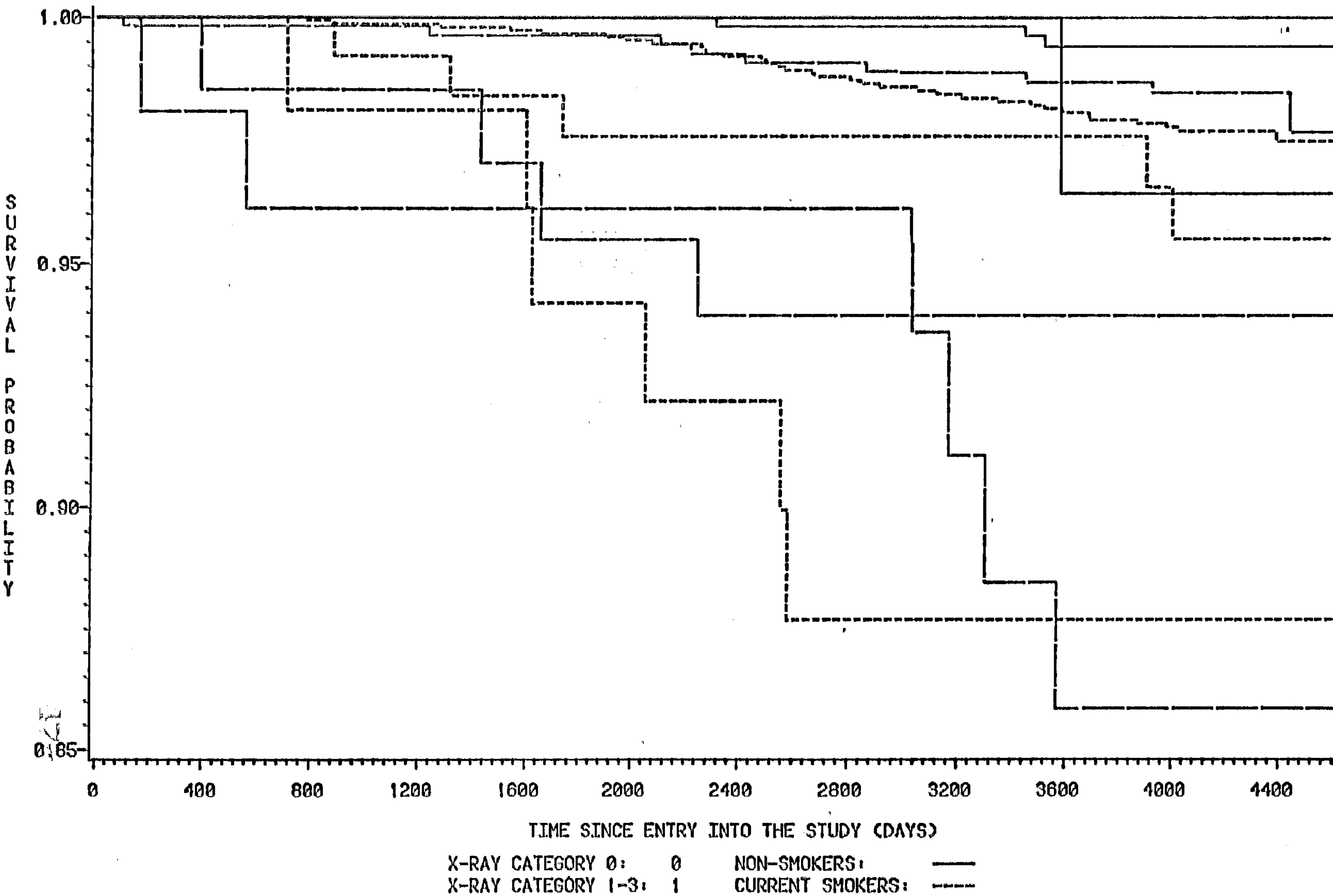


FIGURE 6
KAPLAN-MEIR SURVIVAL PROBABILITIES OF DEATH FROM
NON-MALIGNANT RESPIRATORY DISEASE BY
PACK YEARS FOR EX-MINERS

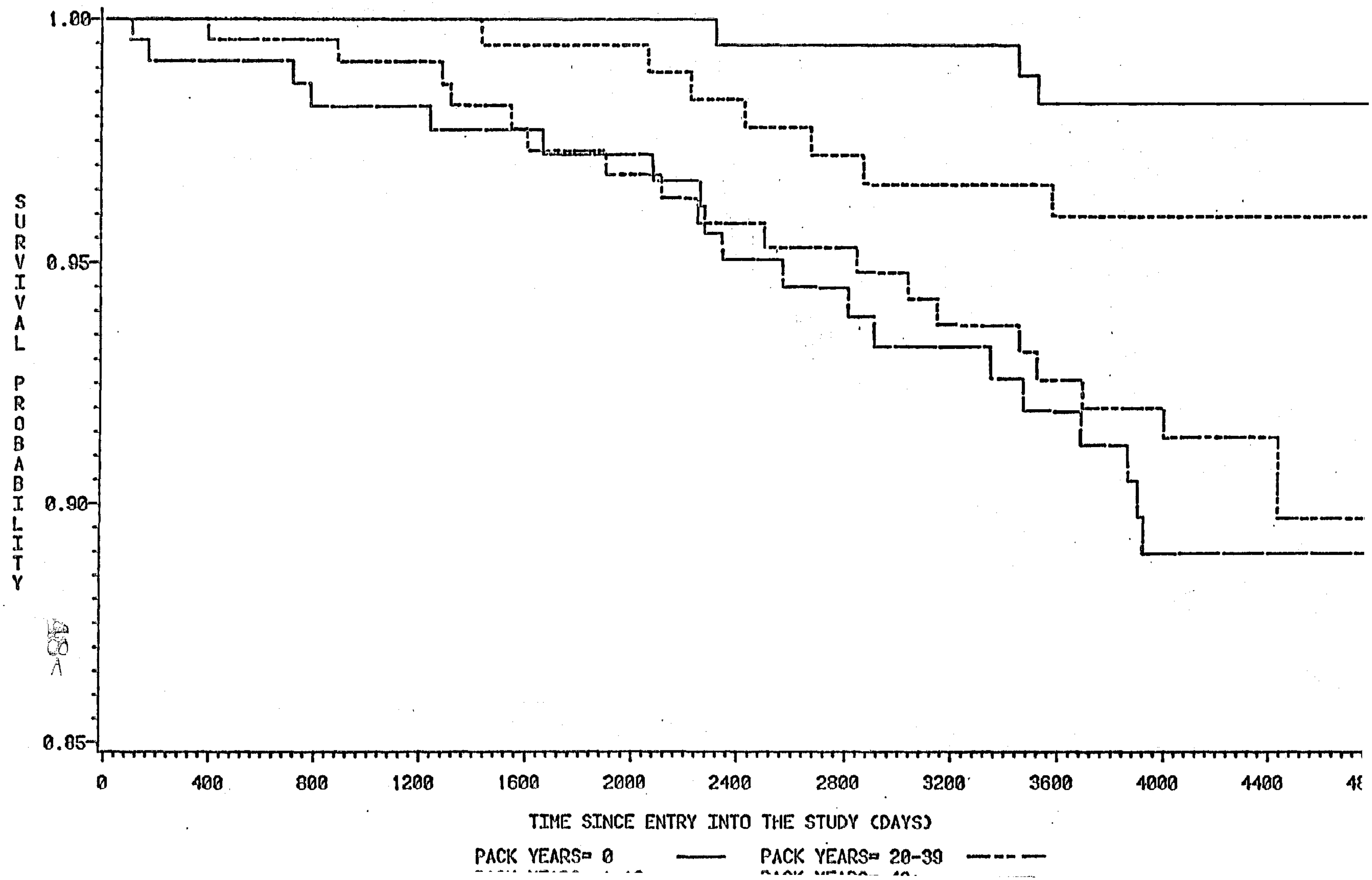


TABLE 13

SMR's FOR LUNG CANCER

VARIABLES	TOTAL GROUP	MINERS X-RAY CATEGORY 0	1-3	PMF	TOTAL	EX-MINERS X-RAY CATEGORY 0	1-3	PMF	TOTAL
YEARS UNDERGROUND									
<30	62.4	53.0	-	-	60.1	26.2*	-	-	66.6
>30	103.2	97.7	150.2	-	130.3	58.5	153.4	187.3	82.2
SMOKING STATUS									
NONSMOKER	7.0*+	0	-	-	0	17.3*+	-	-	13.5*+
CURRENT SMOKER	150.5*	118.4	322.9*	-	151.0*	70.6	474.3*	-	149.8
EX-SMOKER	39.8*	36.2	-	-	43.0	47.2	-	-	37.0
$FEV_1/FVC\%$									
<70	66.5	48.8*	224.9	-	69.0	33.6	151.4	-	62.4
>70	108.4	135.1	75.0+	-	147.3	43.2	232.1	79.8	75.3
BRONCHITIS									
YES	119.1	173.5	-	-	178.3	45.2	-	-	80.8
NO	75.4	52.4*	158.5	282.1	72.4	49.9	264.7	70.8	79.6
DYSPNEA									
YES	92.5	108.3	-	-	80.2	49.6	218.1	231.7	97.1
NO	82.6	68.8	206.7	-	94.4	40.0	225.9	-	57.8
OTHER DUSTY EXPOSURE									
0	86.4	75.1	129.7	302.7*	90.6	54.6*	163.9	183.3	81.2
>1	86.1	61.5	-	-	112.7	0	-	-	69.8
PACK YEARS									
1-19	52.9	65.5	-	-	56.0	42.0	-	-	49.4
20-39	140.1	114.2	-	-	120.3	73.6	-	-	168.0
40+	140.9	109.7	278.1*	-	162.5*	70.7	-	-	113.7
TOTAL	86.0	74.2	154.5	296.8*	91.8	48.0*	214.3	171.3	79.4

TOTAL GROUP: X-RAY CATEGORY 0 = 62.4*

CATEGORY 1-3 = 182.2*

PMF = 217.1*

* Significant at 5% level.
\- Expected number less than 1.
\+ One observed death.

FIGURE 7
KAPLAN-MEIR SURVIVAL PROBABILITIES OF DEATH FROM
LUNG CANCER BY X-RAY CATEGORY AND SMOKING

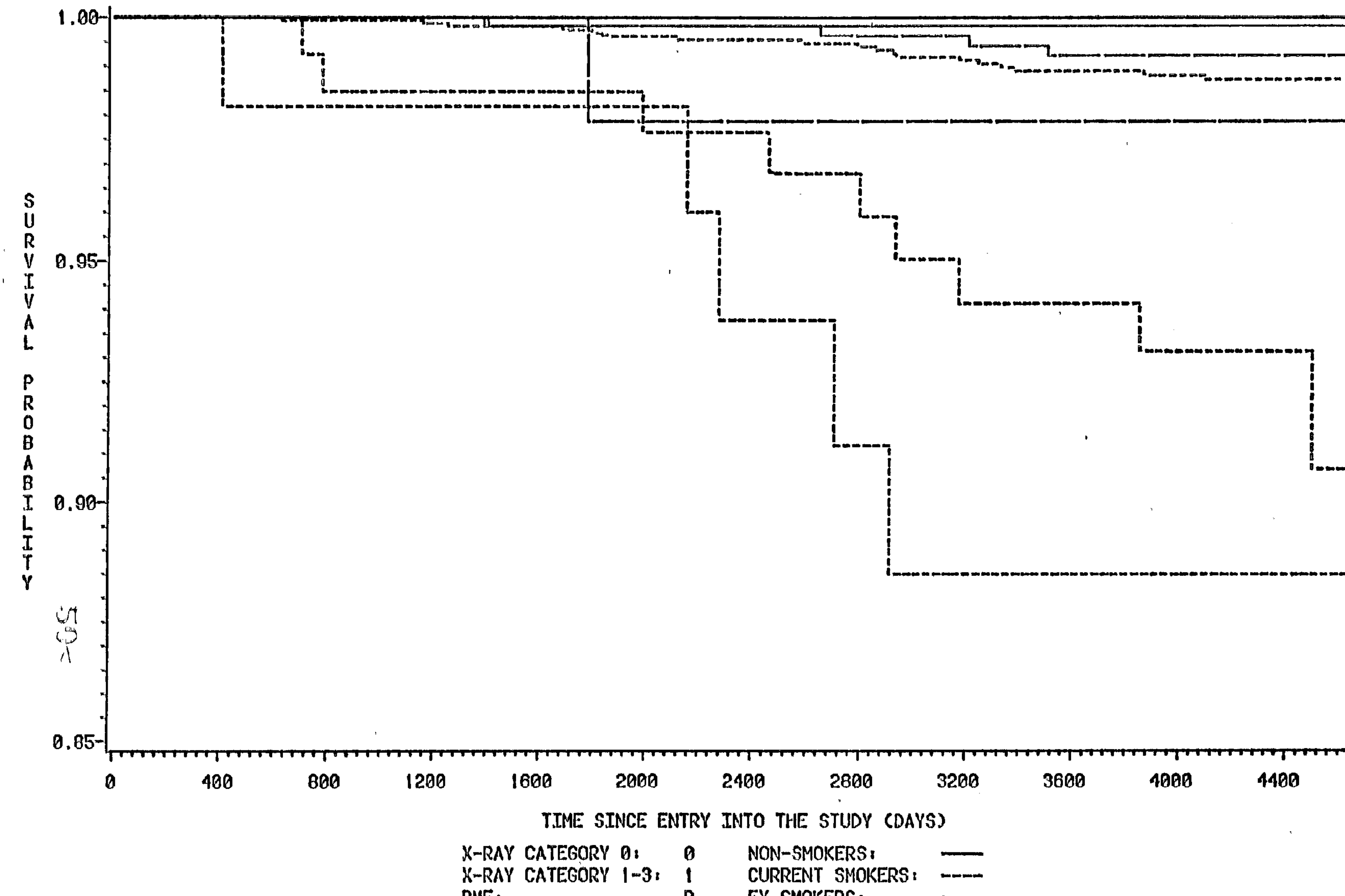


TABLE 14

SMR's FOR DIGESTIVE CANCER

VARIABLES	TOTAL GROUP	MINERS X-RAY CATEGORY 0	MINERS 1-3	MINERS PMF	MINERS TOTAL	EX-MINERS X-RAY CATEGORY 0	EX-MINERS 1-3	EX-MINERS PMF	EX-MINERS TOTAL
YEARS UNDERGROUND									
≤30	71.7	82.7	-	-	75.1	63.0	-	-	66.6
>30	64.3	41.5	128.6	-	51.9	77.2	59.2	73.1	73.1
SMOKING STATUS									
NONSMOKER	43.0*	70.7	-	-	57.6	20.0	-	-	31.2
CURRENT SMOKER	75.4	56.9	85.8	-	57.3	126.4	0	-	100.2
EX-SMOKER	81.6	71.7	-	-	75.6	73.3	-	-	86.4
$FEV_1/FVC\%$									
≤70	72.4	74.6	0	-	64.5	79.4	89.5	-	84.0
>70	66.6	48.6	-	-	51.6	100.5	0	0	78.0
BRONCHITIS									
YES	95.7	175.6	-	-	166.4	71.8	-	-	55.0
NO	59.3*	38.4*	52.2	-	37.6*	83.2	123.2	81.3	86.0
DYSPNEA									
YES	72.5	35.6	-	-	78.1	70.6	86.7	68.3	70.8
NO	68.1	68.0	0	-	58.2	92.8	87.2	-	86.1
OTHER DUSTY EXPOSURE									
0	65.2*	67.3	85.3	-	65.3	64.2	96.1	53.5	65.2
≥1	104.9	0	-	-	0	198.6	-	-	162.2
PACK YEARS									
1-19	67.2	44.7	-	-	38.0	99.4	-	-	97.4
20-39	44.9	93.1	-	-	81.7	0	-	-	0
40+	101.2	58.8	182.5	-	72.2	150.0	-	-	133.7
TOTAL	68.3*	62.9	81.3	-	61.3	78.8	83.8	50.0	75.3

TOTAL GROUP: X-RAY CATEGORY 0 = 70.5

CATEGORY 1-3 = 82.3

PMF = 32.9

* Significant at 5% level.
\- Expected number less than 1.

TABLE 15

SMR's FOR ACCIDENTS

VARIABLES	TOTAL GROUP	MINERS X-RAY CATEGORY 0	1-3	PMF	TOTAL	EX-MINERS X-RAY CATEGORY 0	1-3	PMF	TOTAL
YEARS UNDERGROUND									
≤30	185.9*	206.9*	-	-	197.8*	111.3	-	-	143.2
>30	150.5*	245.8*	-	-	204.6*	112.0	-	-	101.5
SMOKING STATUS									
NONSMOKER	232.9*	263.2	-	-	249.6*	132.2	-	-	208.0
CURRENT SMOKER	188.0*	232.4*	-	-	217.3*	132.1	-	-	107.4
EX-SMOKER	93.8	165.5	-	-	139.0	40.8	-	-	31.9
FEV_1/FVC%									
≤70	161.9*	199.0*	-	-	186.7*	79.0	-	-	85.7
>70	180.7*	303.8*	-	-	272.7*	53.9	-	-	63.0
BRONCHITIS									
YES	208.8*	227.8*	-	-	225.0*	215.2	-	-	193.6
NO	166.3*	224.4*	76.0	-	203.9*	52.3	-	-	70.5
DYSPNEA									
YES	96.4	136.5	-	-	106.3	96.5	-	-	91.5
NO	202.1*	237.0*	156.0	-	222.9*	121.9	-	-	122.7
OTHER DUSTY EXPOSURE									
0	182.6*	238.8*	61.8	-	214.6*	118.1	-	-	114.5
≥1	86.9	.0	-	-	84.0	-	-	-	90.7
PACK YEARS									
1-19	151.4	182.0*	-	-	180.1*	97.8	-	-	77.8
20-39	200.7*	224.7*	-	-	203.5	250.7*	-	-	194.9
40+	130.8	220.6*	-	-	187.7*	34.9	-	-	28.3
TOTAL	174.9*	224.5*	118.3	-	207.0*	104.2	182.8	-	110.8

TOTAL GROUP: X-RAY CATEGORY 0 = 187.0*

CATEGORY 1-3 = 143.1

PMF = 63.9

* Significant at 5% level.
\- Expected number less than 1.

TABLE 16

SUMMARY OF RESULTS

ALL CAUSES

(1) Age, current smoking, PMF, dyspnea, airways obstruction, and mining status increased the risk of death from all causes within 14 years above that expected from U.S. white males. Age was the predominant factor followed by FEV_1, smoking, and PMF which contributed more to excess mortality than did dyspnea, or mining status.

(2) Premature death was not found among those who had categories 0-3 and who: (a) smoked less than 20 pack years, or (b) did not have obstruction, bronchitis, or dyspnea.

(3) The mortality was similar between those with category 0 and 1-3 and between non and ex-smokers.

(4) SMR results were similar to those reported by Ortmeyer after 10 years of follow-up.

ISCHEMIC HEART DISEASE

(1) Death from IHD was associated with age, mining status, other dusty exposures, pack years, dyspnea, FEV_1, and weight. Results are consistent with those reported by Costello (1975).

(2) X-ray category and years underground were not significantly associated with IHD mortality.

(3) Smoking more than 40 pack years of cigarettes was associated with an elevated SMR, particularly among ex-miners. A similar trend was noted for those who had smoked 20-39 pack years but was not statistically significant.

NONMALIGNANT RESPIRATORY DISEASE (NMRD)

(1) Excess mortality was found from influenza, bronchitis, and all other respiratory diseases.

(2) Airways obstruction contributed most to mortality from NMRD followed by age and PMF, and then smoking.

(3) The combination of ex-smoking and category 1-3 was associated with a significant risk.

(4) SMR's were statistically significant among miners when linked with obstruction and other dusty exposures. They were also elevated (but not statistically) when coupled with smoking, bronchitis, dyspnea, and greater than 30 years underground.

Table 16, continued

(5) A marked effect of coal mine dust exposure on NMRD mortality was indicated by a linear trend in SMR's over x-ray category and a significant PMF term in the regression model.

(6) No excess mortality was found among nonsmokers or those without obstruction, but the effect of dust, free of smoking, could not be measured by an SMR due to a small number of expected deaths among PMF nonsmokers.

LUNG CANCER

(1) X-ray category was associated with lung cancer mortality but only among current smokers. The numbers at risk of non and ex-smokers with categories 1-3 and PMF were too small to determine if x-ray category had an independent effect or was interactive with smoking.

(2) Risks were significant after 40 pack years. SMR's were elevated after 20 pack years, but did not reach statistical significance.

(3) Excess mortality was not associated with years underground, non or ex-smokers, airways obstruction, bronchitis, dyspnea, or other dusty exposures.

DIGESTIVE CANCER

(1) An excess mortality was not found from digestive cancer. Only age was a significant risk factor.

ACCIDENTS

(1) Miners had a significant excess of deaths due to accidents, while no excesses were found for ex-miners.