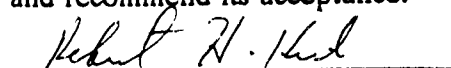


To the Graduate Council:

I am submitting herewith a dissertation written by Joseph L. Weaver entitled "The Healthy Worker Effect: Does Socioeconomic Status Influence Cause-Specific Mortality among Retirees at Department of Energy Facilities in Oak Ridge, Tennessee?" I have examined the final copy of this dissertation for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Doctor of Education, with a major in Health.

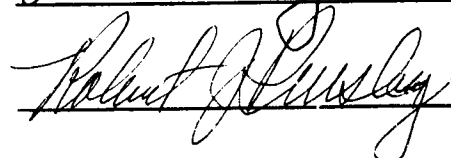

Dr. Bill Wallace
Major Professor

We have read this dissertation
and recommend its acceptance:









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Vice Provost
and Dean of The Graduate School

THE HEALTHY WORKER EFFECT: DOES SOCIOECONOMIC STATUS
INFLUENCE CAUSE-SPECIFIC MORTALITY AMONG RETIREES
AT DEPARTMENT OF ENERGY FACILITIES
IN OAK RIDGE, TENNESSEE?

A Dissertation
Presented for the
Doctor of Education
Degree
The University of Tennessee, Knoxville

Joseph L. Weaver

December 1990

This report concerns work undertaken as part of the Health and Mortality Study of U.S. Department of Energy workers being conducted by Oak Ridge Associated Universities, Oak Ridge, Tennessee, with the collaboration of the University of North Carolina, under contract no. DE-AC05-76OR00033 between the U.S. Department of Energy and Oak Ridge Associated Universities.

The author acknowledges the vital statistics offices of the individual states as the source of death record data and appreciates the offices' technical support of this research. The author is solely responsible for the data analyses and the interpretation of the results.

DEDICATIONS

Over the course of the past four years, I have had the pleasure to have had relationships with some extraordinary people. Among these people are a very special few who helped to keep me focused on my research efforts, and for this, I will remember them always. I would like to dedicate this dissertation to those individuals who gave unselfishly of themselves without asking for anything in return.

I wish to express my gratitude to Professors Bob Kirk and Jack Pursley for teaching me that knowledge is perpetual and, for that reason, a scholar must think not only with his head but also with his heart. This dissertation is especially dedicated to my wife, Deane, my daughter, Amanda, and my son, Mynatt. Their love and support were unwavering through it all--the moments of frustration, depression, happiness, and triumph. I cherish them dearly, and I hope that I can always be there for them in their times of need.

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To my doctoral chairperson, Dr. Bill Wallace, I offer my gratitude for all of the numerous energies that he expended in helping to create the ideas for this research. His personal touch in providing solutions to problems and his patience in reading and editing my work is greatly appreciated.

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ABSTRACT

Many epidemiologic studies have shown that mortality rates of occupational groups are usually lower than those of the general population. This favorable health status has been termed the "healthy worker effect." The primary purpose of this retrospective cohort mortality study was to examine the magnitude of the healthy worker effect between white and blue collar populations and to attempt to determine to what extent this phenomenon effectively continued following retirement.

The mortality experience of 4,444 retirees (4,057 white males and 387 white females) of the Oak Ridge National Laboratory, the Oak Ridge Gaseous Diffusion Plant, and the Y-12 Plant (all located in Oak Ridge, Tennessee) was evaluated for the years 1960 through 1979. This study emphasized the mortality experience of the salaried and hourly retirees who were employed at least 10 years and who lived a minimum of 30 days beyond their retirement dates.

Historical follow-up was conducted for the years 1960 to 1984, and ascertainment of vital status was achieved for 99.6% of the male cohort and 99.9% of the female cohort. There were 43,807.78 person-years of observation. Standardized mortality ratios were computed to contrast the subjects' cause-specific mortality experience with that of a standardized population within the study cohort and with that of the general U.S. population. In the total three-plant population there were 1,620 male deaths and 73 female deaths observed for the all causes category. These deaths comprised 106% and 84%, respectively, of the total numbers of deaths expected.

Several distinct phases were used to examine various subgroups within the study cohort. The initial phase examined the overall death rate among white salaried males across the three Oak Ridge facilities by comparing it to the U.S. average. Overall mortality among

salaried male retirees was found to be essentially as expected for all causes at the Oak Ridge Gaseous Diffusion Plant (SMR = 1.01) and at the Y-12 Plant (SMR = 1.00). However, the mortality rate at the Oak Ridge National Laboratory was less than expected (SMR = 0.90).

In the next phase the white collar cohort was combined and compared to a similar segment of the U.S. population. For the all causes category the mortality experience remained favorable in this combined white collar group (SMR = 0.97). Death rates from cause-specific mortality among the white collar population was also found to be generally better than that of the U.S. This finding supported the postulation that the healthy worker effect continues after an individual retires. Socioeconomic status was implicated as a primary contributor in the good health characteristics found in the salaried male cohort.

The next phase of this study examined the overall mortality experience among white hourly males across the three facilities by comparing it to the general U.S. population. Overall mortality among blue collar retirees was slightly higher than expected in the Oak Ridge National Laboratory (SMR = 1.09) and the Y-12 Plant (SMR = 1.06) populations. The increase in mortality at these two sites was found not to be significant. However, a statistically significant increase in mortality from all causes combined was found in the Oak Ridge Gaseous Diffusion Plant (SMR = 1.17) hourly male population.

In the next phase the blue collar population was combined and compared to the U.S. The death rate for all causes in the combined group was found to be significantly elevated. A significantly elevated mortality rate was found in this population for the all cancers category. There was no evidence of carryover in the healthy worker effect in the blue collar cohort. Several causal factors (i.e., socioeconomic status, lifestyle, and occupational hazards) were identified as major contributors for these findings.

The last phase of the male investigation directly compared the combined white collar male group to the combined blue collar male group. This comparison showed statistically significant increases in the mortality rates in the all causes category (SMR = 1.24). Two cause-specific categories--all cancers (SMR = 1.45) and circulatory diseases (SMR = 1.23)--were found to be significantly elevated in the blue collar population when directly compared to the white collar population.

Relative to the U.S. white female population, both the combined salaried and combined hourly female cohort exhibited fewer deaths in many categories of diseases. Specifically, fewer deaths were recorded in the all causes (salaried SMR = 0.87; hourly SMR = 0.76), all cancers (salaried SMR = 0.91; hourly SMR = 0.93), and the diseases of the circulatory system (salaried SMR = 0.70; hourly SMR = 0.61) categories. These results were indicative of the healthy worker effect, and the lower-than-expected standard mortality ratios observed in the female cohort were probably due to the selection of healthy workers at the first date of hire. The low mortality ratios could also be attributed to neither the hourly nor the salaried females having socioeconomic dominance over the other (but generally better than the U.S. average for those groups).

Further evidence of a healthy worker effect was found in the white and blue collar female population when they were compared to one another. In fact, virtually no differences in overall death rates were found between white and blue collar females when they were compared to each other for all causes (SMR = 1.08), all cancers (SMR = 1.11), and diseases of the circulatory system (SMR = 1.08). Although no evidence was provided to support the postulation, it is suspected that a common link for the congruence in death rates between the two female populations may be attributed to their lifestyle similarities during the study period.

In this study mortality appeared to be highly associated with socioeconomic status. In other words, multi-factorial variables (i.e., health-related behavior, diet, and potential exposure to radiation, organic chemicals, metals, or other substances) may have come together over time to cause adverse mortality outcome in certain subgroups within the study population. The persistently high standard mortality ratios observed in the hourly male retirees suggest that socioeconomic status or related factors had a profound effect on health status over time. Conversely, the persistently low ratios observed throughout the follow-up period in the salaried male population and the entire female population suggest that the healthy worker effect does not diminish in retirement years.

This study also demonstrated that males (both white and blue collar) who retired before age 62 were at an elevated risk of mortality from all causes. The implication made relative to this finding is that a large proportion of male retirees may be leaving the workforce because of health reasons.

The mortality experiences found in this study population underscore the fact that further follow-up is needed in order to examine the independent and combined effects of potential work-related exposures and lifestyle behaviors.

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CHAPTER I

INTRODUCTION

It has been well documented that in the United States and in other developed countries there has been an unprecedented rise in life expectancy. For example, in 1950 the life expectancy was 62.5 years for white males and 72.2 years for white females (see Table 1). Ten years later in 1960, the life expectancy had risen to 67.4 years for white males and to 74.1 years for white females. In 1970 life expectancy continued to increase for both white males (68.0 years) and white females (75.6 years). Also, the U.S. National Center for Health Statistics in 1970 began to keep "expectation of life at birth" statistics specifically for the black population; the 1970 figures indicated the life expectancy for black males to be 60.0 years and for black females 68.3 years. In 1985 the average life expectancy was 71.0 years for white males and 78.3 years for white females. Conversely, the average life expectancy for black males was 65.3 years, and for black females it was 73.5 years (Vital Statistics of the United States, 1988). It appears that these figures will remain fairly constant throughout this decade and well into the 1990s. It has been estimated that by the year 2050, the average life expectancy at birth may be as high as 75 years for men and 83 years for women (Crimmins, 1984 and Health-United States, 1988).

There is evidence that suggests the increase in longevity observed in the last few decades may be attributed, in part, to a decrease in occupational diseases (Rowland, 1977; Harris, 1981; and McGinnis, 1985). This favorable mortality experience has been termed the "Healthy Worker Effect (HWE)" and subsequently has been reported by other researchers

Table 1. Life expectancy at birth and at 65 years of age, according to race and sex: United States, selected years 1900-1987 (Data based on the National Vital Statistics System)

Specified age & year	All races			Whites			Blacks		
	Both sexes	Male	Female	Both sexes	Male	Female	Both sexes	Male	Female
At birth	Remaining life expectancy in years								
1900 ^{1,2}	47.3	46.3	48.3	47.6	46.6	48.7	33.0	32.5	33.5
1950 ²	68.2	65.6	71.1	69.1	66.5	72.2	60.7	58.9	62.7
1960 ²	69.7	66.6	73.1	70.6	67.4	74.1	63.2	60.7	65.9
1970	70.9	67.1	74.8	71.7	68.0	75.6	64.1	60.0	68.3
1975	72.6	68.8	76.6	73.4	69.5	77.3	66.8	62.4	71.3
1980	73.7	70.0	77.4	74.4	70.7	78.1	68.1	63.8	72.5
1981	74.2	70.4	77.8	74.8	71.1	78.4	68.9	64.5	73.2
1982	74.5	70.9	78.1	75.1	71.5	78.7	69.4	65.1	73.7
1983	74.6	71.0	78.1	75.2	71.7	78.7	69.6	65.4	73.6
1984	74.7	71.2	78.2	75.3	71.8	78.7	69.7	65.6	73.7
1985	74.7	71.2	78.2	75.3	71.9	78.7	69.5	65.3	73.5
1986	74.8	71.3	78.3	75.4	72.0	78.8	69.4	65.2	73.5
Provisional data:									
1985 ²	74.7	71.2	78.2	75.3	71.8	78.7	69.5	65.3	73.7
1986 ²	74.9	71.3	78.3	75.4	72.0	78.9	69.6	65.5	73.6
1987 ²	74.9	71.5	78.3	75.5	72.1	78.8	69.7	65.4	73.8
At 65 years									
1900-1902 ^{1,2}	11.9	11.5	12.2	---	11.5	12.2	---	10.4	11.4
1950 ²	13.9	12.8	15.0	---	12.8	15.1	13.9	12.9	14.9
1960 ²	14.3	12.8	15.8	14.4	12.9	15.9	13.9	12.7	15.1

Table 1. Continued

All races			Whites			Blacks			
Specified age & years	Both sexes	Male	Female	Both sexes	Male	Female	Both sexes	Male	Female
At birth									
1970	15.2	13.1	17.0	15.2	13.1	17.1	14.2	12.5	15.7
1975	16.1	13.8	18.1	16.1	13.8	18.2	15.0	13.1	16.7
1980	16.4	14.1	18.3	16.5	14.2	18.4	15.1	13.0	16.8
1981	16.7	14.3	18.6	16.7	14.4	18.7	15.5	13.4	17.3
1982	16.8	14.5	18.7	16.9	14.5	18.8	15.7	13.5	17.5
1983	16.7	14.5	18.6	16.8	14.5	18.7	15.5	13.4	17.3
1984	16.8	14.6	18.6	16.9	14.6	18.7	15.5	13.5	17.2
1985	16.7	14.6	18.6	16.8	14.6	18.7	15.3	13.3	17.0
1986	16.8	14.7	18.6	16.9	14.8	18.7	15.4	13.4	17.0
Provisional data:									
1985 ²	16.8	14.6	18.6	16.6	14.6	18.7	15.5	13.3	17.2
1986 ²	16.9	14.8	18.6	17.0	14.8	18.8	15.5	13.6	16.9
1987 ²	16.9	14.8	18.6	17.0	14.9	18.7	15.6	13.6	17.2

¹ Death registration area only. The death registration area increased from 10 states and the District of Columbia in 1900 to the coterminous United States in 1933.

² Includes deaths of nonresidents of the United States.

³ Figure is for the all other population.

Table 1. Continued

SOURCES: National Center for Health Statistics: Vital Statistics Rates in the United States, 1940-1960, by R. D. Grove and A. M. Hetzel, DHEW Pub. No. (PHS) 1977. Public Health Service. Washington, U.S. Government Printing Office, 1968; Vital Statistics of the United States, 1970, Vol. II, Mortality Part A. DHEW Pub. No. (HRA) 75-1101. Health Resources Administration. Washington. U.S. Government Printing Office, 1974; Annual summary of births, marriages, divorces, and death, United States, 1985. Monthly Vital Statistics Report, Vol. 34, No. 13 DHS Pub. No. (PHS) 86-1120, Sept. 19, 1986; Annual summary of births, marriages, divorces, and deaths, United States, 1987. Monthly Vital Statistics Report, Vol. 36, No. 13 DHHS Pub. No. (PHS) 88-1120. July 29, 1988. Public Health Service, Hyattsville, MD; Unpublished data from the Division of Vital Statistics; Data computed by the Office of Research and Methodology from data compiled by the Division of Vital Statistics.

(McMichael, 1976; Monson, 1978; and Cragle, et al., 1988). There is a growing body of epidemiologic and demographic literature which suggests that the HWE is readily demonstrated by the inverse relationship between socioeconomic status and mortality rates. In general, the higher the income, occupational, and educational levels of a population, the lower its mortality rate (Mechanic, 1978 and Frome, et al., 1989).

If the HWE is influenced by socioeconomic status, the implication can be made that, because of differences in job status, all workers are not impacted equally by the HWE. As a result, the morbidity and mortality rates of occupational subpopulations may not be necessarily lower than those of a similar subpopulation in the general population. For example, differences in mortality experience for minorities could be the result of work disadvantages throughout their lives (Baum, et al., 1987). Minorities traditionally have worked sporadically in low-status jobs and, consequently, have received poor earnings (Hadley, 1982). Therefore, the overall experience of minorities in the workplace may affect their mortality as they age.

The U.S. Senate Special Committee on Aging (1982) noted that, when compared to the white aged, most of the minority aged are less well educated, have less income, suffer more illness and earlier death, have poorer quality housing and less choice as to where they live and where they work, and in general, have a less satisfying quality of life. The Committee's report supports the hypothesis that minority subpopulations in the workforce may experience less favorable long-term health status. However, in this study minorities were excluded because they comprised only a small percentage of the total retired population.

Need for the Study

Income, occupation, and ethnicity are examples of socioeconomic factors associated with the occurrence of disease, whether an investigation focuses on an individual or an aggregation of individuals (Selvin, Sacks and Merrill, 1980). Illness is, therefore, not an objective condition, but rather a socio-construction which depends on socio-psychological structural, cultural, and physical phenomena. One might postulate that illness may be correlated with the nature of a job performed by a given individual. However, according to McMichael (1976), the nature of the population exposed in the work setting tends to be limited and predictable because the HWE appears to exhibit its greatest impact on workers between the ages 18 to 65. Epidemiological investigations into the HWE and its relationship to aging are not merely the study of disease conditions in older and retired people, but rather the analysis of biological and social factors in younger adults as they progress through their working years.

McMichael (1976) has also suggested that the HWE may not apply equally to various groups within a given study population. Therefore, allowances must be made for variation in the HWE among different employee job classifications (i.e., white collar versus blue collar), different periods of observation, and different causes of death. Additionally, McMichael has suggested that the HWE declines with age, and beginning at the age of retirement (65 years), the individual's health status characteristics will increasingly resemble those of the general population. In fact, McMichael found that the HWE disappears by around age 75. Conversely, Sterling and Weinkam (1986) have concluded that, in general, the HWE does not substantially weaken with age in a given population (white or blue collar) and that the HWE appears to be similar for causes of death that tend to appear early and those that tend to

appear late in life. Length of follow-up appears to be the major contributing factor for different findings between the two studies.

The existing evidence relative to the persistence of the HWE in post-retirement years (age 65 and older) is conflicting. Moreover, the differing points of view about the HWE and its impact on blue versus white collar retired populations persists throughout the literature. Some studies, for example, imply that death rates in older populations correlate negatively with the income status of both white and blue collar retirees (Grossman, 1972; Orcutt, et al., 1977; and Atchley, 1982), while others postulate an insignificant or even positive correlation among death rates for such retired populations (Kilpatrick, 1963; Antonovsky, 1967; Kitagawa and Hauser, 1973; Nagi and Stockwell, 1973; and Hadley and Osei, 1982). Although the factors underlying the latter relationship are not fully understood relative to the association with the HWE, several hypotheses have been offered to explain this apparent paradox. They include the classical study of Antonovsky (1967) who observed the following:

Despite the multiplicity of methods in the 30-odd studies cited, and despite variegated populations surveyed, the inescapable conclusion is that class influences one's chances of staying alive. Almost without exception, the evidence shows that classes differ on mortality.

Antonovsky's theory that health is improved as a result of increased socio-economic status (SES) appears to be the essence of the HWE. In support of Antonovsky's findings, Frome, et al. (1988), in a comprehensive study of mortality of Department of Energy (DOE) contractor employees, stated that SES is the most significant and predictive variable of mortality relative to the HWE.

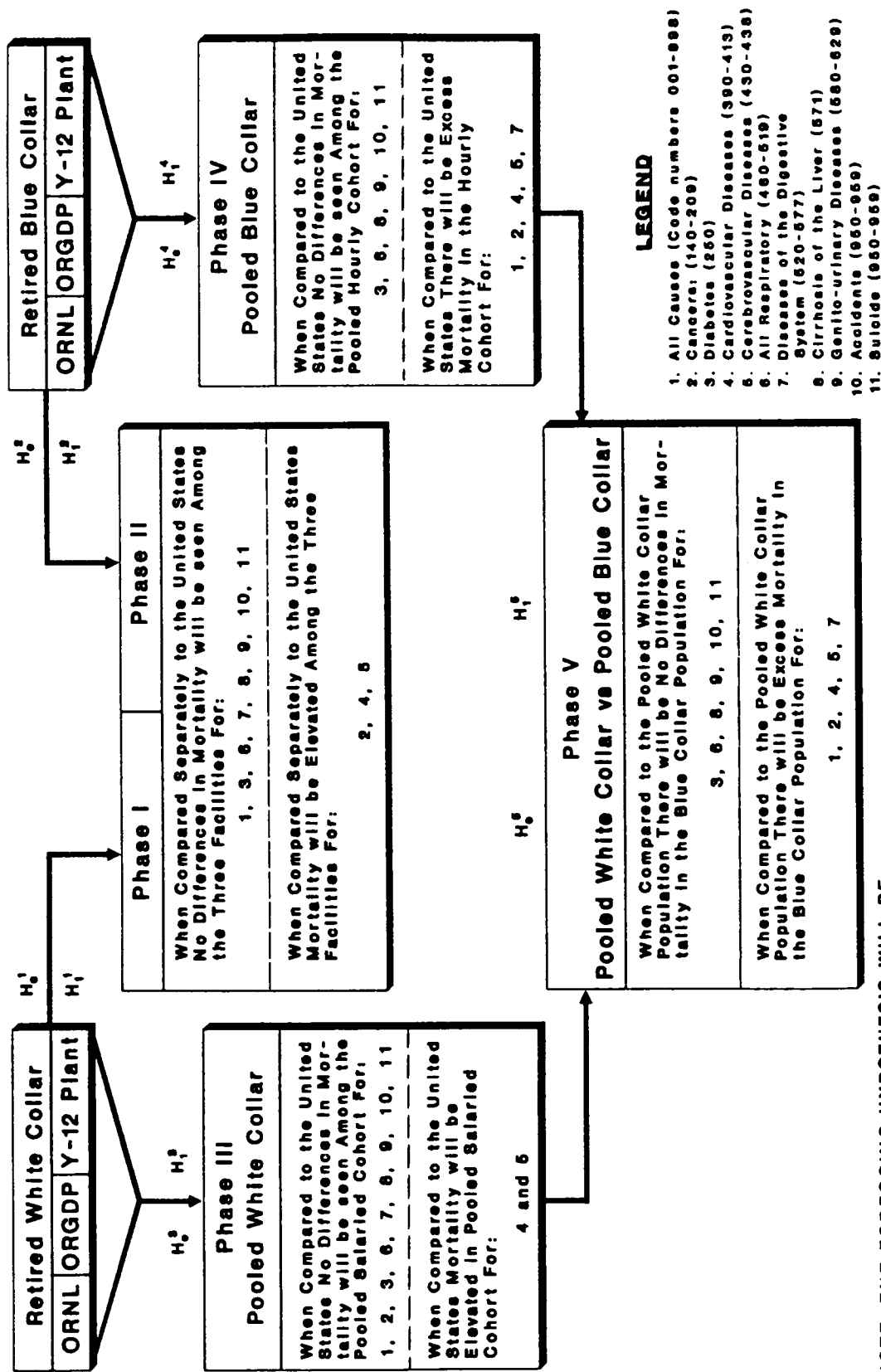
Previously, only a few occupational epidemiological studies have examined retired groups to determine the respective mortality experience among different job classifications (Enterline and Henderson, 1975; Collins and Redmond, 1976; Thomas, et al., 1983; and Fox,

1987). Such studies have reported the mortality results separately for white collar (salaried) and blue collar (hourly) workers. However, many questions remain unexplored. If SES is a powerful determinant of mortality and significantly contributes to the HWE during one's employment years (as suggested by Checkoway, et al., 1985), then this improved survival probability should carry over for several years following retirement (Youngblood and Holloway, 1986 and Monson, 1986).

The primary objective of this study is to extend the HWE research on the general question, "Is SES a significant factor in explaining white collar versus blue collar variations in mortality rates?" To assess this question, this study will utilize vital statistics and survey data that were compiled for the Health and Mortality Study of DOE workers and are maintained on computer tapes by Oak Ridge Associated Universities (ORAU) in Oak Ridge, Tennessee.

The mortality outcomes of both white collar and blue collar retirees from the Oak Ridge National Laboratory (ORNL), the Y-12 Plant (Y-12), and the Oak Ridge Gaseous Diffusion Plant (ORGD)--each located in Oak Ridge, Tennessee and owned by DOE--will be investigated for the years 1960 to 1979 in the following phases (see Figure 1):

1. Compare the differences, if any, in mortality rates among retired white collar workers from ORNL, Y-12, and ORGD for all causes, cancers, diabetes, cardiovascular diseases, cerebrovascular diseases, all respiratory diseases, diseases of the digestive system, genito-urinary diseases, cirrhosis of the liver, accidents, and suicide. If differences exist between these groups and the general U.S. population, they will be seen as an increase in the standard mortality ratio (SMR) with length of follow-up, and the increase will be greatest for cardiovascular deaths and low-to-intermediate for cancer deaths.



NOTE: THE FOREGOING HYPOTHESIS WILL BE REPLICATED FOR THE FEMALE COHORT

Comparison of Cause-Specific Mortality Hypotheses Flowchart

Figure 1

Analysis: SMR by all causes, cancers, diabetes, cardiovascular diseases, cerebrovascular diseases, all respiratory diseases, diseases of the digestive system, genito-urinary diseases, cirrhosis of the liver, accidents, and suicide by length of follow-up, age at retirement, years of employment, job classification, and sex.

2. Repeat comparison among blue collar retired workers from ORNL, Y-12, and ORGDP.

Analysis: Repeat SMR analysis for ten broad cause-of-death groups, length of follow-up, age at retirement, years of employment, job classification, and sex.

3. It has been shown in at least one study (Collins, et al., 1978) that small sample size in a study cohort may not detect significant differences in cause specific death rates when they actually exist. For the purposes of this study, the researcher will attempt to increase the size of the sample by "pooling" the white collar retirees from each facility (ORNL, Y-12, and ORGDP) under investigation; the same technique will be used for blue collar retirees.

- A. The pooled white collar retirees will be used as a standard to directly compare the pooled blue collar retirees to identify differences, if any, in cause-specific mortality rates for ten selected causes of death between the two retired populations. If a difference exists, it will be viewed as an increase in SMR with length of follow-up in the white collar cohort; however, the increase will be greatest for cardiovascular deaths, intermediate-to-low for cancer deaths, and low-to-nonexistent for external causes. Between the two pooled retired groups, SMRs will be intermediate for workers retiring at or after age 65 and high for those individuals

retiring before age 65. In this population of retired workers, SMRs are expected to be highest in the first year of retirement.

Analysis: SMR by all causes, cancers, diabetes, cardiovascular diseases, cerebrovascular diseases, all respiratory diseases, diseases of the digestive system, genito-urinary diseases, cirrhosis of the liver, accidents, and suicide by length of follow-up, age at retirement, sex, SES, and years of employment.

- B. Investigate differences, if any, in the mortality experience between the two pooled retired groups using the U.S. general population as a standard for comparison as follows:

- (1) Pooled retired white collar versus U.S. general population.
- (2) Pooled retired blue collar versus U.S. general population.

If differences exist, they will be seen as an increase in SMR with length of follow-up.

Analysis: Repeat SMR analysis for ten broad cause-of-death groups, length of follow-up, age, sex, and SES.

Statement of the Problem

The purpose of this retrospective cohort mortality study was to determine the extent to which the HWE continues during retirement years by addressing the following research questions:

1. Are there differences in mortality rates among white collar retirees from ORNL, Y-12, and ORGDP when compared to the U.S.?
2. Are there differences in mortality rates among blue collar retirees from ORNL, Y-12, and ORGDP when compared to the U.S.?

3. What influence, if any, does the HWE have on the differences (if any) in survivorship and mortality experience between white collar and blue collar retirees in the two pooled populations under investigation when compared to the U.S. and when compared to each other?
4. What are the expected death rates for the pooled groups when compared to the general population and when compared to each other?

Hypotheses

The following sets of hypotheses express expected relationships between variables and will be used for the analysis of the data:

Hypothesis 1

- A. There are no differences in survivorship and mortality experience for white collar retirees of ORNL, Y-12, or ORGDP when compared individually to the U.S. for all causes, diabetes, all respiratory diseases, diseases of the digestive system, cirrhosis of the liver, genito-urinary diseases, accidents, and suicide.
- B. The mortality experience is higher among white collar retirees for cancers, cardiovascular diseases, and cerebrovascular diseases when compared to the U.S. general population.

Hypothesis 2

- A. There are no differences in survivorship and mortality experience for blue collar retirees of ORNL, Y-12, or ORGDP when compared individually to the U.S. for all causes, diabetes, all respiratory diseases, diseases of the digestive system, cirrhosis of the liver, genito-urinary diseases, accidents, and suicide.
- B. The mortality experience is higher among blue collar retirees for cancers, cardiovascular diseases, and cerebrovascular diseases when compared to the U.S.

general population.

Hypothesis 3

- A. There are no differences in survivorship and mortality experience between the pooled retired white collar population and the pooled retired blue collar population when compared to each other for all causes, cancers, diabetes, all respiratory diseases, diseases of the digestive system, cirrhosis of the liver, genito-urinary diseases, accidents, and suicide.
- B. The mortality experience is higher among the pooled retired blue collar population for cardiovascular diseases and cerebrovascular diseases.

Hypothesis 4

- A. There are no differences in survivorship and mortality experience between the pooled retired white collar population as compared to the U.S. general population for diabetes, all respiratory diseases, cirrhosis of the liver, genito-urinary diseases, accidents, and suicide.
- B. The mortality experience is higher among the pooled retired white collar population for all causes, cancers, cardiovascular diseases, cerebrovascular diseases, and diseases of the digestive system when compared to the U.S. general population.

Hypothesis 5

- A. There are no differences in survivorship and mortality experience between the pooled retired blue collar population as compared to the U.S. general population for diabetes, all respiratory diseases, cirrhosis of the liver, genito-urinary diseases, accidents, and suicide.

- B. The mortality experience is higher among the pooled retired blue collar population for all causes, cancers, cardiovascular diseases, cerebrovascular diseases, and diseases of the digestive system when compared to the U.S. general population.

Basic Assumptions

The research will be based on the following assumptions:

1. The data provided by the DOE and ORAU are valid and reliable as they pertain to the demographic variables being studied.
2. The use of standardized mortality ratios is an acceptable means for analysis of cohort data.
3. The use of mortality rates and the postponement of death is a relevant measure associated with the HWE.

Limitations

The major limitations of the present study are that:

1. The study involves only white males and white females aged 50 and over who had been employed and had retired from ORNL, Y-12, or ORGDP between 1960 and 1979.
2. The study is limited to reporting the cause of death as coded and available on data tapes compiled by ORAU.

Delimitations

The major delimitation of the present study is that the study data collected will be restricted to those on data tapes compiled by ORAU for studies of mortality among workers

employed at ORNL and Y-12 since 1943.

Definition of Terms

The following terms pertain to this study:

1. Aging - An irreversible postmaturational process that correlates over time with increasing functional losses.
2. Blue Collar Worker - Non-exempt employee who was paid on an hourly basis.
3. Cohort - A group of individuals exposed to a similar set of experiences in its workplace.
4. Early Retiree - An individual who had permanently left the DOE-Oak Ridge workforce before normal retirement age (65 years). Early retirement also includes persons who retired due to illness or medical disability.
5. Healthy Worker Effect (HWE) - The underlying expectation of the HWE is that the mortality rate among people who are employed is substantially lower than that of the total general population which includes unemployed persons.
6. Normal Retiree - An individual who had worked at one or more of the facilities under investigation for a combined minimum of 10 or more years and had left the workforce permanently at age 65 or older.
7. Standardized Mortality Ratio (SMR) - Ratio of the number of deaths observed in a study population to the number of deaths expected if the population had the same rate structure as the standard population. Used to minimize the possible error of under-reporting mortality rates.
8. White Collar Worker - Exempt salaried employee who was paid on a monthly or weekly basis.

Organization of the Study

The study consists of six chapters. Chapter I includes the introduction, the need for the study, the statement of the problem, the hypotheses, the basic assumptions, the limitations and delimitations of the study, and the definitions of terms. A review of selected literature relevant to studies similar in content and in methodology is contained in Chapter II. Chapter II also includes a history of the HWE from the 1800s to the present. The research design employed in the study is addressed in Chapter III. Chapter IV presents an analysis and interpretation of the data. The summary, major findings, conclusions, and recommendations are given in Chapter V. Lastly, Chapter VI contains a retrospective of the study.

CHAPTER II

REVIEW OF THE LITERATURE

Evidence was found to suggest that the increase in longevity observed in the last few decades may be attributed, in part, to a decrease in occupational diseases (DHHS, 1988). Researchers have agreed that, in the general population, a more favorable health status will be observed among active workers. This favorable health status is readily demonstrated by low standard mortality ratios (SMRs) and other statistical parameters such as lower morbidity rates, lower mortality rates, and longer life expectancy (Monson, 1978; Syme and Berkman, 1979; Wen, et al., 1983; McLain and Frome, 1985; and Cragle, et al., 1988). Available data and common knowledge suggests that relatively good health is necessary for both initial and continuing employment. As a result, groups of employed persons can have lower mortality rates than those of the general population. This favorable mortality experience has been termed the "Healthy Worker Effect (HWE)" (McMichael, 1976).

The purpose of this review was to organize and condense, in a single convenient format, a large body of literature pertaining to the HWE and its obvious relationship to survivorship and aging. The basic problem of aging in a multistress environment, as viewed by a public health professional, is that it is a complex process caused by mechanisms yet to be defined (Martin, 1979). For this reason, studies relating to mortality and occupation are difficult to interpret. The HWE is principally due to the fact that individuals entering the workforce are considered to be in reasonably good health (Sterling and Weinkam, 1985). Therefore, a similar phenomenon might be expected in a comparison of mortality among

members of an occupational group to that of the general population. The following section provides an overview of the historical prospective and the critical synthesis of previous research and how these studies on aging and mortality trends have impacted the HWE.

Cohort Analysis

Cohort analysis of mortality statistics, which reflect the frequency of death in a population, are routinely collected in many countries. These types of data provide a ready indicator of the frequency of cause-specific mortality as it occurs according to time, place, and individual; and therefore, are important to the health professional's view of disease. In 1870 William Farr first described the cohort analysis of mortality. He stated the following:

The causes that make the rate of mortality vary may be considered under two heads: (1) Causes inherent in the population itself, such, for example, as age and sex and (2) Causes outside the population, such as air, water, food, clothing, dwelling, or such groups of causes as are involved in residence and relation of the several parts to each other in time and space.

In 1930, Andvord attempted to explain the changing age distribution of tuberculosis in London by using Farr's methodology.

By using age-specific tuberculosis mortality rates at 10-year intervals among males in Massachusetts, W. H. Frost (1939) further elaborated on Farr's technique. As a result, Frost concluded that mortality peaks later in life. He suggested that the high rate of mortality due to tuberculosis in the elderly was probably the result of reactivation of an infection acquired early in life and was not necessarily a newly acquired infection.

M. L. Levin (1953) also used cohort analysis of mortality data to investigate lung cancer and its relationship to age-specific death rates. He found that the risk of lung cancer increased between the ages 60 to 69 and declined in ages over 70. Levin also found that the risk of mortality from lung cancer tended to decline even further at 80 years of age. He

suggested that the main reason for the decline was that members in the 80 and older age group had lower exposure to the etiological agent (cigarette smoking) than did later cohorts. Wen, et al. (1984), believed that the mortality peak later in life did not represent the postponement of maximum risk, but meant that the high death rates in old age were the residuals of higher risk rates in earlier ages.

In 1975 Cutler reported on the trends in survival rates of patients with cancer. His development of statistical methods for survivorship analysis proved to be an important resource for researchers conducting occupational studies.

Mortality Patterns in Occupational Cohorts

The fact that there were even earlier accounts of selective influences present in occupational groups was pointed out by Weed in 1985. At the beginning of the 18th century, Bernardino Ramazzini (commonly known as the "Father of Occupational Medicine") developed systematic descriptions of occupational maladies of the workers of Modena, Italy. An example of these systematic descriptions can be found in his list of diseases for "learned men." Ramazzini stated that these individuals suffered from arthritis and nephritis as a result of sedentary employment; had weak vision because they "gazed intently at what they read or write, and so could not fail, to become keenly aware of damage to the vision"; and had weak stomachs because "the stomach could not properly digest its own supply of foods while the brain was digesting what was supplied by the passion for knowledge and the hunger for learning." Thus, according to Ramazzini, these "learned men" ultimately hastened their own deaths because of their passion for knowledge.

Ramazzini, a physician by profession, believed that individuals who were naturally weak-sighted should not be employed in such jobs as cleaning privies and cesspits because

such employment could have led lead to loss of eyesight. He wrote that they should "abandon this sort of occupation and devote themselves to another that they may not for the sake of vile and filthy lucre, lose their sight and be forced to beg." Ramazzini's text remained the fundamental work on occupational diseases during the 18th century.

William Guy, a professor of forensic medicine at King's College Hospital in London, in 1845 studied whether sedentary jobs were "filled with persons naturally unhealthy" who had entered such occupations on the advice of their parents. Guy reasoned that if parents had known that their children were weak or ailing, they would have directed them to enter occupations that required little physical effort. Guy interviewed 503 patients from a variety of occupations in an attempt to determine the role that primary selection (i.e., those entering the workforce) and secondary selection (i.e., those already employed in an occupation incompatible with their health) played in this patient population.

Guy came to the conclusion that "in only one case of fifty does (the) state of health exercise any influence on the selection (of an occupation)." As a result of Guy's efforts, he should probably be credited with the first epidemiologic study of the selection processes commonly held to be responsible for the HWE. One should be aware, however, that Guy's study only begins to answer the question of occupational selection and its relationship to the HWE. Since his study, other researchers have presented evidence to prove that an individual's health does exercise a significant and direct influence on the selection of an occupation (Collins, 1976; Shindell, et al. 1978; Lilenfeld, 1979; Swartz and Epstein, 1981; Austin and Schnatter, 1983; Ames and Trent, 1984; Sweeney, et al. 1985; and Carpenter, et al, 1987).

Much information obviously can be drawn from these epidemiologic studies. However, to better understand the HWE, one must become familiar with the phenomenon

of aging. Although aging may be thought of as a normal physiological process, it includes both positive (e.g., self actualization and greater sense of self) and negative aspects (e.g., marked physical decline on virtually any measure, including speed, strength, work capacity, elasticity and system functioning). Such chronic conditions contribute to the limitation of activity as shown in Tables 2 and 3. Experience, sagacity, and wisdom also come with age; so aging is not a totally detrimental process.

Aging

Phillips and Gaylord (1984 and 1985) have defined aging in biological terms as the postmaturational process that correlates over time with increasing functional losses. Individuals vary greatly in the rate at which these processes occur. Palmore (1985) defined aging as a process that cannot be reversed. Therefore, one would expect the incidences of chronic illness to increase as people age. According to Hendricks (1979), 88% of the 23 million people over the age of 65 in the United States reported at least one diagnosed chronic condition in 1979. The incidence of diagnosed chronic illness appears to be closely correlated with age (Hendricks, 1979).

Studies of the relationship between retirement and health have suggested that retirement may bring a sense of inadequacy and rolelessness and may increase the risk of health problems, leading to illness and even death (Palmore, 1972; Blau, 1973; and Verbrugge, 1985). Conversely, illness may lead to retirement. For example, Rowland (1977) and Sweeney, et al. (1985), found that blue-collar workers retired for reasons of poor health. However, the cohort analyses on which these studies were based had serious methodological limitations when they attempted to chart changes over time (Monson, 1986). It is questionable whether observed changes are the result of cohorts experiencing different

Table 2. Limitation of activity caused by chronic conditions, according to selected characteristics:
United States, 1983 and 1987.

(Data are based on household interviews of a sample of the civilian noninstitutionalized population)

Characteristic	Total with limitation of activity		Limited but not in major activity		Limited in amount or kind of major activity		Unable to carry on major activity	
	1983	1987	1983	1987	1983	1987	1983	1987
Total ^{1,2}	13.8	12.9	4.1	4.0	6.0	5.2	3.6	3.7
Percent of population								
Age								
Under 15 years	4.8	4.7	1.3	1.3	3.1	3.0	0.4	0.4
Under 5 years	2.1	2.1	0.5	0.7	1.1	1.0	0.5	0.5
5-14	6.2	6.2	1.8	1.7	4.1	4.1	0.3	0.4
15-44 years	8.5	8.1	2.7	2.6	3.9	3.4	1.9	2.0
45-64 years	24.3	22.3	5.9	5.6	10.2	8.2	8.2	8.5
65 years & over	40.2	37.5	14.8	14.7	15.0	12.9	10.4	10.0
65-74 years	37.6	34.7	13.5	12.8	13.3	11.3	10.7	10.7
75 years & over	44.4	41.9	16.8	17.7	17.7	15.4	9.9	8.9
Sex ¹								
Male	13.9	12.9	3.8	3.8	5.6	4.8	4.6	4.3
Female	13.6	12.8	4.5	4.2	6.4	5.5	2.7	3.1
Race ¹								
White	13.4	12.7	4.2	4.1	5.9	5.2	3.3	3.4
Black	17.5	16.0	3.8	3.5	7.5	6.2	6.2	6.2

Table 2. Continued

Characteristic	Total with limitation of activity		Limited but not in major activity		Limited in amount or kind of major activity		Unable to carry on major activity	
	1983	1987	1983	1987	1983	1987	1983	1987
Percent of population								
Family income ¹								
Less than \$10,000	23.0	23.9	5.4	5.2	9.6	9.2	8.0	9.4
\$10,000-\$14,999	16.6	17.4	4.5	4.5	6.8	6.9	5.2	6.0
\$15,000-\$19,999	14.4	13.9	4.3	4.0	6.6	5.6	3.5	4.3
\$20,000-\$34,999	11.0	11.2	3.7	3.7	5.1	4.8	2.1	2.7
\$35,000 or more	9.4	8.9	3.7	3.6	4.1	3.7	1.6	1.6

¹Age adjusted.²Includes all other races not shown separately and unknown family income.

SOURCE: Division of Health Interview Statistics, National Center for Health Statistics: Data from the National Health Interview Survey.

Table 3. Disability days associated with acute conditions and incidence of acute conditions, according to age: United States, 1982-87.

(Data are based on household interviews of a sample of the civilian noninstitutionalized population)

Age	1982	1983	1984	1985	1986	1987
Restricted-activity days						
Number per person						
All ages ¹	6.5	7.2	7.4	6.8	7.7	6.8
Under 15 years	7.0	8.2	7.9	6.9	8.2	7.5
Under 5 years	7.2	9.5	8.8	7.5	9.0	9.4
5-14 years	6.8	7.5	7.4	6.7	7.8	6.6
15-44 years	6.2	6.6	7.1	6.5	7.0	6.5
45-64 years	5.9	6.3	6.6	6.0	7.0	6.1
65 years and over	7.4	9.2	9.1	9.6	10.2	8.0
65-74 years	7.0	8.7	8.3	8.9	10.2	8.2
75 years and over	7.9	10.1	10.2	10.9	10.1	7.7
Bed-disability days ²						
All ages ¹	3.0	3.4	3.3	3.1	3.4	3.0
Under 15 years	3.3	4.0	3.6	3.4	3.8	3.4
Under 5 years	3.7	4.7	3.8	3.5	3.9	4.4
5-14 years	3.1	3.6	3.5	3.3	3.8	2.8
15-44 years	2.9	3.0	3.2	2.8	3.1	2.8
45-64 years	2.5	2.8	2.6	2.7	3.1	2.6
65 years and over	3.3	4.5	3.9	3.9	4.6	3.4
65-74 years	3.1	4.4	3.7	2.8	3.9	3.7
75 years and over	3.6	4.7	4.3	5.7	5.5	3.0

Table 3. Continued

(Data are based on household interviews of a sample of the civilian noninstitutionalized population)

Age	1982	1983	1984	1985	1986	1987
Incidence of acute conditions ³						
Number per 100 persons						
All ages ¹	174.6	182.9	184.9	183.1	189.52	180.8
Under 15 years	271.1	288.1	289.3	280.0	302.7	281.7
Under 5 years	326.3	354.5	345.1	334.6	360.4	358.9
5-14 years	242.9	252.8	259.2	250.9	271.7	240.4
15-44 years	160.1	165.1	172.2	170.1	180.5	168.7
45-64 years	106.7	109.3	104.4	112.9	125.1	101.4
65 years and over	92.1	100.9	98.8	98.4	119.5	100.4
65-74 years	97.3	103.1	97.4	98.9	118.2	94.8
65 years and over	83.4	97.3	101.0	97.7	121.5	109.4

¹Age adjusted.²A subset of restricted-activity days.³Excludes conditions involving neither medical attention nor activity restriction.

SOURCE: Division of Health Interview Statistics, National Center for Health Statistics: Data from the National Health Interview Survey.

social-structural and cultural environments or if these changes occur to cohort members as they age. The most supportive assertion is based on longitudinal studies that follow people through retirement and demonstrate that ill-health does not increase in the years immediately following retirement (Streib and Schneider, 1971; Atchley, 1976; Cottrell, 1969; and Baum and Baum, 1980).

A significant observation made by Marshall (1980) was that there is some evidence that older people are less likely than younger people to recognize disease or physiological assaults, and a majority are likely to perceive themselves as "healthy for my age." People with chronic conditions may consider that the day-to-day adjustment to the condition, such as diabetes or heart disease, constitutes good health, while a worsening of the chronic condition or acute illness may be seen as grounds for perceiving oneself in poor health. Illness is obviously not an objective condition, but rather a social construction which depends on social-psychological structural, cultural, and physical phenomena and their interpretation. Thus, the epidemiology of aging is not merely the study of disease conditions in older people, but encompasses the analysis of biological and social factors in younger adults that affect their health in later years.

Mortality Trends

The U.S. population aged 65 and over has been increasing rapidly both in number and proportion. This rise is attributable to the declines in mortality and fertility. As evidence of this fact, McGinnis (1985) pointed out that for the first time in recorded history the life expectancy increase in infants is exceeded by the life expectancy increase for some adults. In the first 10 years of this century, the life expectancy increase for infants was on the order of about 4%, whereas the life expectancy for adults at age 65 actually decreased. On the

other hand, during the years 1970 to 1980 there was an increase of life expectancy for infants of slightly over 4%, while the life expectancy for adults increased slightly over 6%. These increases represent a 50% gain in life expectancy over the last 60 years (McGinnis, 1985).

According to the U.S. Department of Health and Human Services (1988), between the years 1940 and 1978 death rates decreased by 16.7% for males over age 65 and 33.0% for females over the age of 65. However, the decline in death rates is even more dramatic for the population aged 65 and over when adjusted for changes in overall age composition. When age-specific death rates are examined for the period 1940 to 1978, death rates showed a decline of 24.5% for the males age 65 and over and 46.7% for females in that same age-range (DHHS, 1988).

Other data sources have shown that elderly mortality can be summarized as follows:

1. Between the years 1940 and 1978 the mortality rate for persons 65 and older decreased by 27% (DHHS, 1980).
2. In 1983 the decline in mortality rates was two times greater for women than men; 33% versus 17% (U.S. Bureau of the Census, 1984).
3. The 1980 census reported that 11.3% of the U.S. population (25.12 million people) was over age 65 (U.S. Senate, Special Committee on Aging, 1982).
4. By the year 2000 the elderly population is expected to increase by 30%, while the population under 65 will probably increase by only 15% (U.S. Senate, Special Committee on Aging, 1982).
5. If fertility remains at low levels and mortality rates continue to decline, the proportion of elderly persons in the U.S. could approach 18% by the year 2020 (DHHS, 1988).

6. In the 1980 census there were 65 men for every 100 women aged 65 and older. Projections for the year 2000 estimate a rate of 60 elderly men for every 100 elderly women. The sex differential is greater among persons 85 years and older: 44 men for every 100 women (U.S. Senate Special Committee on Aging, 1982).
7. Persons 85 years and older constitute the fastest growing group of elderly people. Since 1900 this age-group has grown seventeenfold, while the population aged 75 years and older has increased ten times, and the population over age 60 has increased almost seven times. In 1975 persons over age 85 comprised 8% of the elderly population. It is projected that this group will comprise 11% of the elderly population in the year 2000 (DHHS, 1980).
8. According to DHHS (1988), the ten leading causes of death by sex, race, and age for all ages in the U.S. population for the years 1950-1986 were as follows (see Tables 4 and 5 for more descriptive data): (1) Diseases of the heart; (2) Cerebrovascular diseases; (3) Malignant neoplasms; (4) Chronic obstructive pulmonary diseases; (5) Pneumonia and influenza; (6) Chronic liver disease and cirrhosis; (7) Diabetes mellitus; (8) Accidents; (9) Suicide; and (10) Homicide. Of these categories of diseases, items 1-7 are traditionally associated with the HWE (Cragle, et al., 1988).
9. Chronic diseases are major causes of mortality in the elderly. With the exception of some cancers, the mortality rates are decreasing for all leading chronic diseases (DHHS, 1988).

Table 4. Death rates for all causes, according to sex, race, and age:
United States, selected years 1950-86.

Sex, race, and age	1950 ¹	1960 ¹	1970	1980	1983	1984	1985	1986
Deaths per 100,000 resident population								
All races								
All ages, age adjusted	841.5	760.9	714.3	585.8	550.5	545.9	546.1	541.7
All ages, crude	963.8	954.7	945.3	878.3	862.8	862.3	873.9	873.2
Under 1 year	3,299.2	2,696.4	2,142.4	1,288.3	1,107.3	1,085.6	1,067.8	1,032.1
1-4 years	139.4	109.1	84.5	63.9	55.9	51.9	51.4	52.0
5-14 years	60.1	46.6	41.3	30.6	26.9	26.7	26.3	26.0
15-24 years	128.1	106.3	127.7	115.4	96.0	96.8	95.9	102.3
25-34 years	178.7	146.4	157.4	135.5	121.4	121.1	123.4	132.1
35-44 years	358.7	299.4	314.5	227.9	201.9	204.8	207.2	212.9
45-54 years	853.9	756.0	730.0	584.0	535.7	521.1	516.3	504.8
55-64 years	1,911.7	1,735.1	1,658.8	1,346.3	1,299.5	1,287.8	1,282.7	1,255.1
65-74 years	4,067.7	3,822.1	3,582.7	2,994.9	2,874.3	2,848.1	2,838.6	2,801.4
75-84 years	9,331.1	8,745.2	8,004.4	6,692.6	6,441.5	6,399.3	6,445.1	6,348.2
85 years and over	20,196.9	19,857.5	17,539.4	15,980.3	15,168.0	15,223.6	15,480.3	15,398.9
White male								
All ages, age adjusted	963.1	917.7	893.4	745.3	698.4	689.9	688.7	679.8
All ages, crude	1,089.5	1,098.5	1,086.7	983.3	957.4	951.1	960.0	954.4

Table 4. Continued

Sex, race, and age	1950 ¹	1960 ¹	1970	1980	1983	1984	1985	1986
Under 1 year	3,400.5	2,694.1	2,113.2	1,230.3	1,052.9	1,038.4	1,033.9	976.6
1-4 years	135.5	104.9	83.6	66.1	57.3	51.8	52.4	52.2
5-14 years	67.2	52.7	48.0	35.0	31.1	30.5	29.9	29.9
15-24 years	152.4	143.7	170.8	167.0	137.0	138.8	136.3	145.9
25-34 years	185.3	163.2	176.6	171.3	154.8	154.3	157.1	168.8
35-44 years	380.9	332.6	343.5	257.4	232.9	235.1	241.4	248.4
45-54 years	984.5	932.2	882.9	698.9	636.5	617.9	608.8	592.2
55-64 years	2,304.4	2,225.2	2,202.6	1,728.5	1,642.9	1,625.5	1,614.3	1,573.1
65-74 years	4,864.9	4,848.4	4,810.1	4,035.7	3,816.1	3,745.3	3,716.8	3,634.8
75-84 years	10,526.3	10,299.6	10,098.8	8,829.8	8,556.9	8,459.1	8,500.4	8,341.7
85 years and over	22,116.3	21,750.0	20,392.6	19,097.3	18,443.3	18,552.7	18,788.9	18,576.1
Black male								
All ages, age adjusted	1,373.1	1,246.1	1,318.6	1,112.8	1,019.6	1,011.7	1,024.0	1,026.9
All ages, crude	1,260.3	1,181.7	1,186.6	1,034.1	963.3	958.1	976.8	987.7
Under 1 year		5,306.8	4,298.9	2,586.7	2,243.4	2,136.6	2,134.8	2,181.7
1-4 years	1,412.6	208.5	150.5	110.5	96.8	85.2	89.0	90.9
5-14 years	95.1	75.1	67.1	47.4	40.9	42.4	41.3	42.0
15-24 years	289.7	212.0	320.6	209.1	165.0	163.9	174.1	190.5
25-34 years	503.5	402.5	559.5	407.3	335.8	335.6	374.4	385.6
35-44 years	878.1	762.0	956.6	689.8	586.5	616.0	641.8	675.9
45-54 years	1,905.0	1,624.8	1,777.5	1,479.9	1,287.3	1,273.5	1,283.3	1,266.5
55-64 years	3,773.2	3,316.4	3,256.9	2,873.0	2,713.1	2,658.3	2,623.1	2,545.5
65-74 years	5,310.3	5,798.7	5,803.2	5,131.1	4,949.3	4,874.5	4,888.7	4,789.9
75-84 years		8,605.1	9,454.9	9,231.6	9,100.0	9,023.1	9,298.4	9,290.8
85 years and over	10,101.9	14,844.8	14,415.4	16,098.8	14,155.6	14,642.9	15,046.2	15,488.1

Table 4. Continued

Sex, race, and age	1950 ¹	1960 ¹	1970	1980	1983	1984	1985	1986
White female								
All ages, age adjusted	645.0	555.0	501.7	411.1	392.7	391.3	390.6	387.7
All ages, crude	803.3	800.9	812.6	806.1	815.3	822.3	837.1	840.7
Under 1 year	2,566.8	2,007.7	1,614.6	962.5	837.6	818.5	786.9	759.1
1-4 years	112.2	85.2	66.1	49.3	43.9	41.6	39.7	40.7
5-14 years	45.1	34.7	29.9	22.9	19.7	20.0	19.4	18.6
15-24 years	71.5	54.9	61.6	55.5	48.3	49.6	48.4	50.4
25-34 years	112.8	85.0	84.1	65.4	60.1	59.5	58.9	60.4
35-44 years	235.8	191.1	193.3	138.2	123.4	123.9	121.2	121.3
45-54 years	546.4	458.8	462.9	372.7	351.0	341.9	339.5	330.3
55-64 years	1,293.8	1,078.9	1,014.9	876.2	867.8	864.9	864.1	853.3
65-74 years	3,242.8	2,779.3	2,470.7	2,066.6	2,024.7	2,032.5	2,028.3	2,031.8
75-84 years	8,481.5	7,696.6	6,698.7	5,401.7	5,162.2	5,140.0	5,171.4	5,108.7
85 years and over	19,679.5	19,477.7	16,729.5	14,979.6	14,278.3	14,319.6	14,579.4	14,502.9
Black female								
All ages, age adjusted	1,106.7	916.9	814.4	631.1	590.4	585.3	589.1	588.2
All ages, crude	1,002.0	905.0	829.2	733.3	711.2	712.0	727.7	733.9
Under 1 year	4,162.2	3,368.8	2,123.7	1,818.6	1,679.1	1,756.6	1,731.1	
1-4 years	1,139.3	173.3	129.4	84.4	73.6	72.2	70.3	76.5
5-14 years	72.8	53.8	43.8	30.5	28.0	27.8	28.1	26.9
15-24 years	213.1	107.5	111.9	70.5	65.6	61.6	59.5	64.3
25-34 years	393.3	273.2	231.0	150.0	130.0	130.6	136.3	146.5
35-44 years	758.1	568.5	533.0	323.9	276.1	285.7	278.4	290.2
45-54 years	1,576.4	1,177.0	1,043.9	768.2	685.8	655.0	654.0	654.6

Table 4. Continued

Sex, race, and age	1950 ¹	1960 ¹	1970	1980	1983	1984	1985	1986
55-64 years	3,089.4	2,510.9	1,986.2	1,561.0	1,526.3	1,489.7	1,501.7	1,469.8
65-74 years	4,000.2	4,064.2	3,860.9	3,057.4	2,930.6	2,907.4	2,925.7	2,892.3
75-84 years	6,730.0	6,691.5	6,212.1	6,064.6	6,184.1	6,252.0	6,148.8	
85 years and over	8,347.0	13,052.6	12,131.7	12,367.2	11,329.5	11,329.5	12,154.7	12,510.3

¹Includes deaths of nonresidents of the United States.

SOURCES: National Center for Health Statistics: Vital Statistics of the United States, Vol. II, Mortality, Part A, 1950-86. Public Health Service. Washington. U.S. Government Printing Office; Data computed by the Division of Analysis from data compiled by the Division of Vital Statistics and from Table 1.

Table 5. Age-adjusted deaths rates for the ten most frequent causes of death, according to sex and race: United States, selected years 1950-86.

(Data are based on the National Vital Statistics Systems)

Sex, race, & cause of death	1950 ¹	1960 ¹	1970	1980	1983	1984	1985	1986
All races	Deaths per 100,000 resident population							
All causes	841.5	760.9	714.3	585.8	550.5	545.9	546.1	541.7
Diseases of heart	307.6	286.2	253.6	202.0	188.8	183.6	180.5	175.0
Cerebrovascular diseases	88.8	79.7	66.3	40.8	34.4	33.4	32.3	31.0
Malignant neoplasms	125.4	125.8	129.9	132.8	132.6	133.5	133.6	133.2
Respiratory system	12.8	19.2	28.4	36.4	37.9	38.4	38.8	39.0
Colorectal	19.0	17.7	16.8	15.5	14.9	15.0	14.8	14.4
Prostate ²	13.4	13.1	13.3	14.4	14.6	14.5	14.6	15.0
Breast ³	22.2	22.3	23.1	22.7	22.7	23.2	23.2	23.1
Chronic obstructive pulmonary disease	4.4	8.2	13.2	15.9	17.4	17.7	18.7	18.8
Pneumonia and influenza	26.2	28.0	22.1	12.9	11.8	12.2	13.4	13.5
Chronic liver disease and cirrhosis	8.5	10.5	14.7	12.2	10.2	10.0	9.6	9.2
Diabetes mellitus	14.3	13.6	14.1	10.1	9.9	9.5	9.6	9.6
Accidents and adverse effects	57.5	49.9	53.7	42.3	35.3	35.0	34.7	35.2
Motor vehicle accidents	23.3	22.5	27.4	22.9	18.5	19.1	18.8	19.4
Suicide	11.0	10.6	11.8	11.4	11.4	11.6	11.5	11.9
Homicide and legal intervention	5.4	5.2	9.1	10.8	8.6	8.4	8.3	9.0

Table 5. Continued.

Sex, race, and cause of death	1950 ¹	1960 ¹	1970	1980	1983	1984	1985	1986
White male								
All causes	963.1	917.7	893.4	745.3	698.4	689.9	688.7	679.8
Diseases of heart	381.1	375.4	347.6	257.8	249.8	249.5	244.5	234.8
Cerebrovascular diseases	87.0	80.3	68.8	41.9	35.2	33.9	32.8	31.1
Malignant neoplasms	130.9	141.6	154.3	160.5	158.9	159.0	159.2	158.8
Respiratory system	21.6	34.6	49.9	58.0	58.0	58.4	58.2	58.0
Colorectal	19.8	18.9	18.9	18.3	17.8	17.8	17.6	17.2
Prostate	13.1	12.4	12.3	13.2	13.4	13.3	13.3	13.8
Chronic obstructive pulmonary disease	6.0	13.8	24.0	26.7	27.6	27.6	28.5	28.1
Pneumonia and influenza	27.1	31.0	26.0	16.2	15.3	15.8	17.4	17.5
Chronic liver disease and cirrhosis	11.6	14.4	18.8	15.7	13.4	13.2	12.6	12.2
Diabetes mellitus	11.3	11.6	12.7	9.5	9.2	9.0	9.2	9.1
Accidents and adverse effects	80.9	70.5	76.2	62.3	51.8	51.3	50.4	51.1
Motor vehicle accidents	35.9	34.0	40.1	34.8	27.8	28.4	27.6	28.7
Suicide	18.1	17.5	18.2	18.9	19.3	19.7	19.9	20.5
Homicide and legal intervention	3.9	3.9	7.3	10.9	8.4	8.2	8.1	8.4

Table 5. Continued.

Sex, race, and cause of death	1950 ¹	1960 ¹	1970	1980	1983	1984	1985	1986
Black male								
All causes	1,373.1	1,246.1	1,318.6	1,112.8	1,019.6	1,011.7	1,024.0	1,026.9
Diseases of heart	415.5	381.2	375.9	327.3	308.2	300.1	301.0	294.3
Cerebrovascular diseases	146.2	141.2	124.2	77.5	64.2	62.8	60.8	58.9
Malignant neoplasms	126.1	158.5	198.0	229.9	232.2	234.9	231.6	229.0
Respiratory system	16.9	36.6	60.8	82.0	83.3	85.9	84.4	83.9
Colorectal	13.8	15.0	17.3	19.2	19.0	19.9	19.5	19.3
Prostate	16.9	22.2	25.4	29.1	29.9	29.7	30.3	30.3
Chronic obstructive pulmonary disease		---	---	---	20.9	22.2	22.8	23.9
24.6								
Pneumonia and influenza	63.8	70.2	53.8	28.0	24.3	25.2	26.8	27.2
Chronic liver disease and cirrhosis	8.8	14.8	33.1	30.6	22.8	22.5	23.4	20.8
Diabetes mellitus	11.5	16.2	21.2	17.7	17.7	17.6	17.7	17.9
Accidents and adverse effects	105.7	100.0	119.5	82.0	66.2	64.7	66.7	66.9
Motor vehicle accidents	39.8	38.2	50.1	32.9	26.4	27.2	27.7	29.2
Suicide	7.0	7.8	9.9	11.1	10.5	11.2	11.3	11.5
Homicide and legal intervention	51.1	44.9	82.1	71.9	53.8	50.8	49.9	55.9

Table 5. Continued.

Sex, race, and cause of death	1950 ¹	1960 ¹	1970	1980	1983	1984	1985	1986
White female								
All causes	645.0	555.0	501.7	411.1	392.7	391.3	390.6	387.7
Diseases of heart	223.6	197.1	167.8	134.6	126.7	124.0	121.7	119.0
Cerebrovascular diseases	79.7	68.7	56.2	35.2	29.6	28.9	27.9	27.1
Malignant neoplasms	119.4	109.5	107.6	107.7	108.5	109.9	110.3	110.1
Respiratory system	4.6	5.1	10.1	18.2	21.0	21.6	22.6	23.1
Colorectal	19.0	17.0	15.3	13.3	12.5	12.8	12.3	12.0
Breast	22.5	22.4	23.4	22.8	22.7	23.1	23.3	23.0
Chronic obstructive pulmonary disease	2.8	3.3	5.3	9.2	11.3	11.8	12.9	13.3
Pneumonia and influenza	18.9	19.0	15.0	9.4	8.6	8.8	9.8	9.9
Chronic liver disease and cirrhosis	5.8	6.6	8.7	7.0	6.0	5.9	5.6	5.4
Diabetes mellitus	16.4	13.7	12.8	8.7	8.6	8.0	8.1	8.1
Accidents and adverse effects	30.6	25.5	27.2	21.4	18.3	18.5	18.4	18.4
Motor vehicle accidents	10.6	11.1	14.4	12.3	10.3	10.9	10.8	11.0
Suicide	5.3	5.3	7.2	5.7	5.6	5.6	5.3	5.4
Homicide and legal intervention	1.4	1.5	2.2	3.2	2.8	2.9	2.9	2.9

Table 5. Continued.

Sex, race, and cause of death	1950 ¹	1960 ¹	1970	1980	1983	1984	1985	1986
Black female								
All causes	1,106.7	916.9	814.4	631.1	590.4	585.3	589.1	588.2
Diseases of heart	349.5	292.6	251.7	201.1	191.5	186.6	186.8	185.1
Cerebrovascular diseases	155.6	139.5	107.9	61.7	53.8	51.8	50.3	47.6
Malignant neoplasms	131.9	127.8	123.5	129.7	129.8	131.0	130.4	132.1
Respiratory system	4.1	5.5	10.9	19.5	22.0	21.4	22.5	23.3
Colorectal	15.0	15.4	16.1	15.3	15.1	15.3	16.1	15.2
Breast	19.3	21.3	21.5	23.3	24.4	26.1	25.3	25.8
Chronic obstructive pulmonary disease	---	---	---	6.3	7.6	8.1	8.7	8.9
Pneumonia and influenza	50.4	43.9	29.2	12.7	10.2	11.3	12.4	13.1
Chronic liver disease and cirrhosis	5.7	8.9	17.8	14.4	10.8	10.3	10.1	9.3
Diabetes mellitus	22.7	27.3	30.9	22.1	21.1	20.5	21.1	21.4
Accidents and adverse effects	38.5	35.9	35.3	25.1	21.9	20.1	20.7	21.0
Motor vehicle accidents	10.3	10.0	13.8	8.4	7.5	7.6	8.2	8.5
Suicide	1.7	1.9	2.9	2.4	2.1	2.3	2.1	2.4
Homicide and legal intervention	11.7	11.8	15.0	13.7	11.2	11.0	10.8	11.8

¹Includes deaths of nonresidents of the United States.²Male only.³Female only.

Table 5. Continued.

NOTE: For data years shown, the code numbers for cause of death are based on the then current International Classification of Diseases, which are described in Appendix II, tables IV and V.

SOURCES: National Center for Health Statistics; Vital Statistics Rates in the United States, 1940-1960, by R. D. Grove and A. M. Hetzel. DHEW Pub. No. (PHS) 1677. Public Health Service. Washington, U.S. Government Printing Office, 1968; Unpublished data from the Division of Vital Statistics; Vital Statistics of the United States, Vol. II, Mortality, Part A, 1950-86. Public Health Service. Washington. U.S. Government Printing Office; Data computed by the Division of Analysis from data compiled by the Division of Vital Statistics and from table 1.

10. Death rates from all causes increase with age. In 1977 deaths per 1,000 of the non-institutionalized population rose from 24.8 among persons aged 65 to 69 years; to 88.1 among those aged 80 to 84 years; and to 147.3 for those aged 85 years and older (DHHS, 1988).
11. Black males show the highest death rate in the 65 to 79 age category; after age 80, there is a crossover and white males show higher death rates (DHHS, 1988).
12. The black female death rate is higher than the white female death rate until age 80, whereupon the white female death rate exceeds it (DHHS, 1988).

The aforementioned characteristics set the stage for a close examination of the HWE and its association with survivorship.

Critical Synthesis of Previous Research

In terms of pathologic processes, the diseases that cause the most mortality in the U.S. are those with long-term latency and those that become chronic only after a sufficient period of exposure or time since first exposure and are, therefore, most evident at older ages (McMichael, 1976). Phillips and Gaylord (1985) indicated the death rates from all causes increase with age. For example, Bourliere (1970) showed that heart disease, cancer, and strokes together cause three out of four deaths within the 65 and older age group. These are significant observations since these mortality trends appear to be the result of biohazardous exposure. Therefore, in terms of the HWE, a reasonable assumption might be that younger people are more likely to demonstrate the survival advantage that results from their initial better-than-community average health status.

In a survivorship study of the retired age range 65-84, McMichael also found that the HWE no longer operates actively. The residual survival advantage declines with age as the retirees come to increasingly resemble the general population in their health status characteristics. In fact, in his work he found that the HWE disappears by around age 75.

Occupational epidemiology studies frequently suffer from the HWE selection bias because they use U.S. population data as the comparison when calculating SMRs. While the choice of a general population as the comparison is the underlying reason for this effect, it appears that a better accepted alternative is not yet available (Wen, Tsai and Gibson, 1983). As a result of such a comparison, the HWE becomes evident when SMRs are calculated for a certain occupation. These studies suggest that there is still knowledge to be gained regarding the variables that may influence the nature of the HWE.

For example, several researchers (Altenderfer, 1947; Antonovsky, 1967; Orcutt, et al., 1977; and Hadley and Osei, 1982) have advocated the theory that SES is the one true variable most frequently used to measure health relative to U.S. mortality (see Table 6). The theory that health is improved as a result of increased SES is the essence of the HWE. Additional credence was given to the theory that SES is linked to good health in a 1964 American Medical Association (AMA) report. The AMA reported the following:

Medical science does not seek major credit for the improvements in the health level during the past 25 years. Certainly, our standards of living and higher education levels have contributed substantially to the betterment of the health level in the United States.

Such statements tend to indicate that SES may impact the mortality of various occupational groups within a given workforce.

Some researchers (Hadley and Osei, 1982) suggest that SES (e.g., higher income) is associated with lower mortality. The results of the Hadley and Osei study showed that SES had a much more positive impact on elderly cohorts age 65 years and older than the younger

Table 6. Self-assessment of health, according to selected characteristics:
United States, 1983 and 1987.

(Data are based on household interviews of a sample of the civilian noninstitutionalized population)

Characteristic	Total	Excellent		Very Good		Good		Fair or poor	
		1983	1987	1983	1987	1983	1987	1983	1987
Percent of population									
Total ^{1,2}	100.0	40.7	40.3	25.4	27.8	23.2	22.4	10.7	9.5
Age									
Under 15 years	100.0	53.3	53.9	24.9	27.2	18.8	16.5	3.0	2.4
Under 5 years	100.0	54.0	54.0	25.1	27.4	18.0	16.1	2.9	2.6
5-14	100.0	52.9	53.9	24.8	27.1	19.3	16.8	3.1	2.3
15-44 years	100.0	44.7	43.2	27.9	30.5	21.5	20.9	6.0	5.4
45-64 years	100.0	26.6	27.3	24.0	26.5	29.3	28.8	20.1	17.4
65 years and over	100.0	16.6	15.4	19.2	20.9	30.8	32.9	33.3	30.8
65-74 years	100.0	16.9	16.7	19.1	21.6	31.7	33.5	32.3	28.2
75 years and over	100.0	16.2	13.4	19.4	19.9	29.4	31.9	34.9	34.9
Sex ¹									
Male	100.0	43.0	42.6	25.0	27.4	21.8	21.0	10.2	9.0
Female	100.0	38.6	38.2	25.7	28.2	24.6	23.7	11.1	9.9
Race ¹									
White	100.0	42.6	42.1	25.8	28.2	22.1	21.1	9.6	8.5
Black	100.0	28.5	29.5	21.8	24.4	30.0	29.4	19.7	16.7

Table 6. Continued

Characteristic	Total	Excellent		Very Good		Good		Fair or poor	
		1983	1987	1983	1987	1983	1987	1983	1987
Family income ¹									
Less than \$10,000	100.0	29.1	26.4	22.1	24.1	27.6	28.9	21.2	20.5
\$10,000 - \$14,999	100.0	34.2	31.9	24.8	26.9	27.2	27.1	13.9	14.1
\$15,000 - \$19,999	100.0	37.0	34.7	26.9	28.1	25.7	26.3	10.5	11.0
\$20,000 - \$34,999	100.0	43.7	41.1	27.4	29.2	22.0	22.7	6.9	7.1
\$35,000 or more	100.0	53.1	50.9	26.2	28.0	16.1	16.3	4.7	4.7

¹Age adjusted.²Includes all other races not shown separately and unknown family income.

SOURCE: Division of Health Interview Statistics, National Center for Health Statistics; Data from the National Health Interview Survey.

adults (ages 45-64) in the study cohort. Their findings indicate that the HWE tends to operate more effectively in elderly persons with higher education and income levels (i.e., white collar as compared to blue collar employees). A similar conclusion was reached by Antonovsky in 1967:

Despite the multiplicity of methods in the 30-odd studies cited, and despite variegated populations surveyed, the inescapable conclusion is that class influences one's chances of staying alive. Almost without exception, the evidence shows that classes differ on mortality rates.

Points of view contrary to Hadley and Osei's and Antonovsky's have been offered in other studies: Palmone, 1972; Blau, 1973; and Syme and Berkman, 1979. These studies suggest that intense psychological job association may very well put older white collar workers at a higher risk of mortality upon retirement. Therefore, the HWE may be less observable in retired white collar workers who have intense psychological association with their previous job status.

Yet another point of view is offered by McMichael (1976) who suggests that, regardless of SES, healthy workers will, relative to their health status characteristics, come to increasingly resemble the general population during their retirement years (ages 65-84). McMichael's study, however, demonstrates that there are major differences in the mortality experience between retired subgroups when criteria other than SES is used. For example, the findings of his study indicated that the HWE was greater at all ages for nonwhites than for whites. One must be aware that McMichael's study compared working, healthy, retired nonwhite workers to the general U.S. nonwhite male population, which included those men considered to be at the lower end of the socio-economic scale (i.e., chronically unemployed, indigent, or minimum wage earners). Conversely, McMichael also compared working-class and retired whites to the average middle-class white male American population, which included a smaller proportion of unemployed chronically ill individuals. Because of this, the

quality of the HWE on the comparison of these two race groups is confounded by SES (e.g., class differences).

Clearly, the existing evidence on the HWE does not overflow with parity relative to its persistence in post-retirement years. The research presented in this chapter draws attention to the fact that, historically, many studies of the adverse effects of retirement and aging on health have compared the mortality rates of a group of retired persons to the mortality rates of the general population. As a result, some studies imply that mortality rates tend to be negatively correlated with the HWE and aging, while others postulate an insignificant or positive correlation. Although the factors underlying the relationship between the HWE and an individual's post-retirement years are not fully understood, several hypotheses have been offered to explain this apparent paradox. They include the works of Monson (1986), who like McMichael (1976), believed that the population of the region from which the study group is derived may contain mortality rates that are different from those of the general population of the entire country. Moreover, if such a study group has characteristics of health status that differ from those of the general population in the early years of follow-up, obvious dissimilarities would be expected in the mortality rates. The review of literature on this subject has revealed that there is still much to be learned about the nature of the HWE.

CHAPTER III

DESIGN AND METHODOLOGY

Overview

As stated in the previous chapters of this study, results of many epidemiologic studies have suggested that mortality rates of occupational groups are generally lower than those of the general population. Underlying this favorable health status is the phenomenon known as the "Healthy Worker Effect (HWE)": the reasonable expectation that the mortality rate among persons healthy enough to be employed is different than that of the general population and that difference will persist for some time after an individual retires (Sterling, 1986).

This retrospective cohort mortality study has attempted to examine the magnitude of the HWE between two retired populations (white and blue collar) in order to determine to what extent this phenomenon continued to effectively operate following retirement. To address this subject, this researcher chose to analyze the mortality experiences of male and female workers who retired between the years 1960 and 1979 from three Department of Energy (DOE) facilities located in Oak Ridge, Tennessee: Oak Ridge National Laboratory (ORNL), the Oak Ridge Y-12 Plant (Y-12), and the Oak Ridge Gaseous Diffusion Plant (ORGDP). Standardized mortality data was used to evaluate the ten selected causes of death in the study cohort. Historical follow-up was conducted for the years 1960 through 1984. These data were based on employee job status (i.e., exempt or non-exempt) prepared by the investigator under the guidance of Oak Ridge Associated Universities (ORAU). The vital

status for each group was ascertained from Social Security Administration (SSA) records through the DOE Certificate Retrieval Office, which also retrieved and verified the death certificates for the known dead.

During the course of this study, ORAU nosologists mailed coded data tapes to the SSA at least once every 6 months to assess the vital status of the study population. In addition, ORAU personnel performed searches through the Motor Vehicle Bureaus of several states in an attempt to accurately determine vital status for all DOE-Oak Ridge retirees. Death certificates were requested by ORAU from the appropriate state in which the death occurred. The underlying cause of death recorded on the death certificate was coded by ORAU nosologists according to the rules of the eighth revision of the International Classification of Diseases (ICD8) in effect at the time of death.

Description of Facilities: Past and Present

ORNL, ORGDP, and Y-12 are all located in Oak Ridge, Tennessee and, during the study period was operated for the DOE by Union Carbide Corporation-Nuclear Division (UCC-ND). The overall mission of UCC-ND was to carry out energy research and development, to produce of nuclear weapons components, and to attain other goals of national importance. UCC-ND employed a workforce of approximately 15,000 at the three facilities. Over the past two decades (1960-1979), retirement among the three facilities has been approximately 225 persons per year (5.1% of the study population). Even though each facility is geographically located in the same region, the workforce has a different composition due to historically dissimilar missions. Because of the unique differences within the three facilities, some background information regarding their history is warranted.

Oak Ridge National Laboratory (ORNL)

ORNL was established in 1943 as part of the World War II Manhattan Project. The original mission of ORNL was the production and chemical separation through use of a graphite reactor of the first gram quantities of the manmade element plutonium. The reactor used natural uranium (99.3% U-238) contained in gas-tight cylindrical aluminum jackets for fuel. During the later years of operation, the reactor contained 54 tons of fuel. In 1963 the reactor was shut down as a result of the development of more sophisticated tools for plutonium research.

Today ORNL is a diversified center of research and development of safe, economical, and environmentally acceptable technologies for the efficient production and use of energy. The facility occupies 2,900 acres and employs a workforce of approximately 5,300 full-time research and support personnel. Of this number, approximately 4,300, or 81%, are considered to be white collar workers. The white collar population is characterized as follows: approximately 2,700, or 51%, are monthly salaried, exempt employees (i.e., scientists, engineers, and administrative professionals) and approximately 1,600, or 30%, are weekly salaried, non-exempt employees (i.e., technical and administrative support personnel). Of the ORNL workforce, approximately 1,000, or 19%, are considered to be blue collar workers (i.e., hourly skilled and semi-skilled personnel). Historically, the proportion of white-to-blue collar workers at ORNL has been approximately 4:1.

Oak Ridge Y-12 Plant (Y-12)

Y-12 was built in 1943 with a mission to assist in the World War II effort by separating the fissionable isotopes of uranium (U-235) via the electromagnetic process. This effort involved the use of approximately 1,200 separating units known as calutrons, requiring

an initial capital investment of more than \$500 million and a peak full-time workforce of 23,000 persons. U-235 was the fissionable material used in the production of the world's first atomic bomb that was detonated on August 5, 1945. After World War II, the electromagnetic separation process was discontinued.

Today, Y-12 has two principal missions: (1) Producing nuclear weapons components and supporting the DOE's weapons design laboratories and (2) Processing source and special nuclear material. Y-12 occupies approximately 800 acres and employs a full-time workforce of about 6,800 persons. Of this number, approximately 3,470, or 51%, are considered to be white collar workers. The white collar population is characterized as follows: approximately 2,300, or 34%, are monthly salaried, exempt employees (i.e., scientists, engineers, and administrative professionals) and approximately 1,170 or 17%, are weekly salaried, non-exempt employees (i.e., technical and administrative support personnel). Of the Y-12 workforce, approximately 3,330, or 49%, are considered to be blue collar workers (i.e., hourly skilled and semi-skilled personnel). Historically, the proportion of white-to-blue collar workers at Y-12 has been approximately 3:7.

Oak Ridge Gaseous Diffusion Plant (ORGDP)

ORGDP began operation in 1943 as the world's first facility designed to separate uranium by using the gaseous diffusion process. The initial production goal was to support the World War II Manhattan Project and other national defense programs. During its industrial peak, ORGDP evolved into an internationally recognized center for enriched uranium production and technology development.

ORGDP today occupies 1,500 acres to the west of the City of Oak Ridge and employs some 2,700 persons. The proportion of white-to-blue collar employees has historically been about 1:2. In 1985 ORGDP was placed on standby status, and in 1987 was ordered by the

DOE to phase out production entirely. Presently, ORGDP's principal mission is to support endeavors of other federal agencies through the DOE Work for Others program.

Study Cohort

A computerized data set was constructed from all workers who were employed ≥ 10 years and who terminated between January 1, 1960 and December 31, 1984, from any one of the facilities under investigation. The completed data set contained information regarding race, sex, date of birth, termination date, age at termination, and cause of death. All retirees included in this study were followed through the end of 1984, at which time their vital status was determined. Coded vital status for each retiree was categorized as "alive," "dead," or "unknown," based on computerized data compiled by an experienced ORAU nosologist. In addition, the vital status of the study population as of December 31, 1984, was ascertained through the Social Security Administration. To ensure a minimum of four years of follow-up for everyone in the final cohort, this group was restricted to persons who retired before January 1, 1980. Table 7 summarizes the number of retirees (7,740) and their reason(s) for exclusion or inclusion in the final study population. The study population was further restricted to white males and white females who were either on the hourly payroll or salaried payroll for one year prior to their retirement. Retirees also had to meet the following criteria to be included in the final study population:

1. During the study period, a total of 10 years employment at one or more of the facilities combined was required to be eligible for retirement benefits.
2. Had actually retired (early or normal) from one of the facilities. An early retiree was considered to be an individual who had permanently left the workforce of either facility before normal retirement age (65 years). Individuals

Table 7: Criteria for Personnel Exclusion or Inclusion in Study Population

*Total Number of Retirees 1960 - 1984	7,740
Exclusions:	
Black Males or Other Non-White Males	179
Black Females or Other Non-White Females	49
Retired on or After 1 January 1980	2,499
Erroneous or Unknown Job Title	2
Lived Less Than 30 Days Following Retirement	567
**Final Study Cohort	4,444

*Includes age restriction of at least 50 years old when termination occurs.

**White males and white females who retired from one of the facilities under study between 1 January 1960 and 31 December 1979.

in the early retirement category also included those who retired due to illness, physical, or medical disability. Normal retirement included all those who retired at or after age 65.

3. Had to be at least 50 years of age at date of termination. During the time period encompassed by this study (1960-1979), age 50 was the minimum age at which an individual became eligible to receive retirement benefits.
4. Had to live a minimum of 30 days beyond retirement from any of the Oak Ridge government facilities under investigation. Exclusion of this segment of the cohort was made in an attempt to enhance the generalizability of the mortality data generated by this study.

As defined in earlier chapters, the term "retirement," either early or normal, means the permanent separation due to chronological age, ill health, or disability of an individual from his or her occupational position. It stands to reason that less healthy workers (e.g., those who were dysfunctional in their normal work environment) would tend to have a higher frequency of early retirement than their more healthy counterparts. Therefore, it was not unexpected to find that the computerized mortality data maintained by ORAU indicated that a large percentage (80% or 567) of the 709 retirees who died during their first year of retirees who lived less than 30 days beyond their termination dates.

The high incidences of mortality among individuals who died less than 30 days after their retirement dates may be partially related to the schedules of UCC-ND's benefits program. Payment schemes of the benefits program differ for total and permanent (T&P) disability retirement versus early retirement. For example, terminally ill individuals may be allowed to remain on the payroll for six months, or longer, depending on a physician's diagnosis of a given disease. Once a physician determines that an employee will not be physically capable of returning to work, that individual is granted a T&P. Upon receiving a

T&P, the retiree receives a termination allowance and can draw up to \$20,000 in insurance benefits over a 5-year period. (It should be noted that this scenario does not apply to all T&P retirements.) Conversely, individuals taking early retirement, regardless of medical condition, do not receive similar benefits.

The retirement process was viewed from a broad socioeconomic context within which pay status and survival were used as key variables in the examination of the yearly mortality patterns within this study population. Therefore, the restriction to exclude persons who lived less than 30 days following retirement was imposed to limit the number of T&Ps entering the study population. This restriction allowed for the exclusion of persons who had no real control over their retirement and who had not received any of their accrued pension benefits. Table 8 provides an overview of the number of retirees by facility and year that made up the final study population ($N = 4,444$). Figure 2 displays the retirement pattern for the study cohort by facility for the years 1960-1979.

Person-years were calculated from date of retirement. In all analyses, it appears that retirees with unknown vital status did not contribute person-years past the date that they were last known to be alive, which was usually the date of termination from the facility. The underlying causes of death recorded on the death certificates were assigned ICD8 codes by ORAU nosologists.

Methods

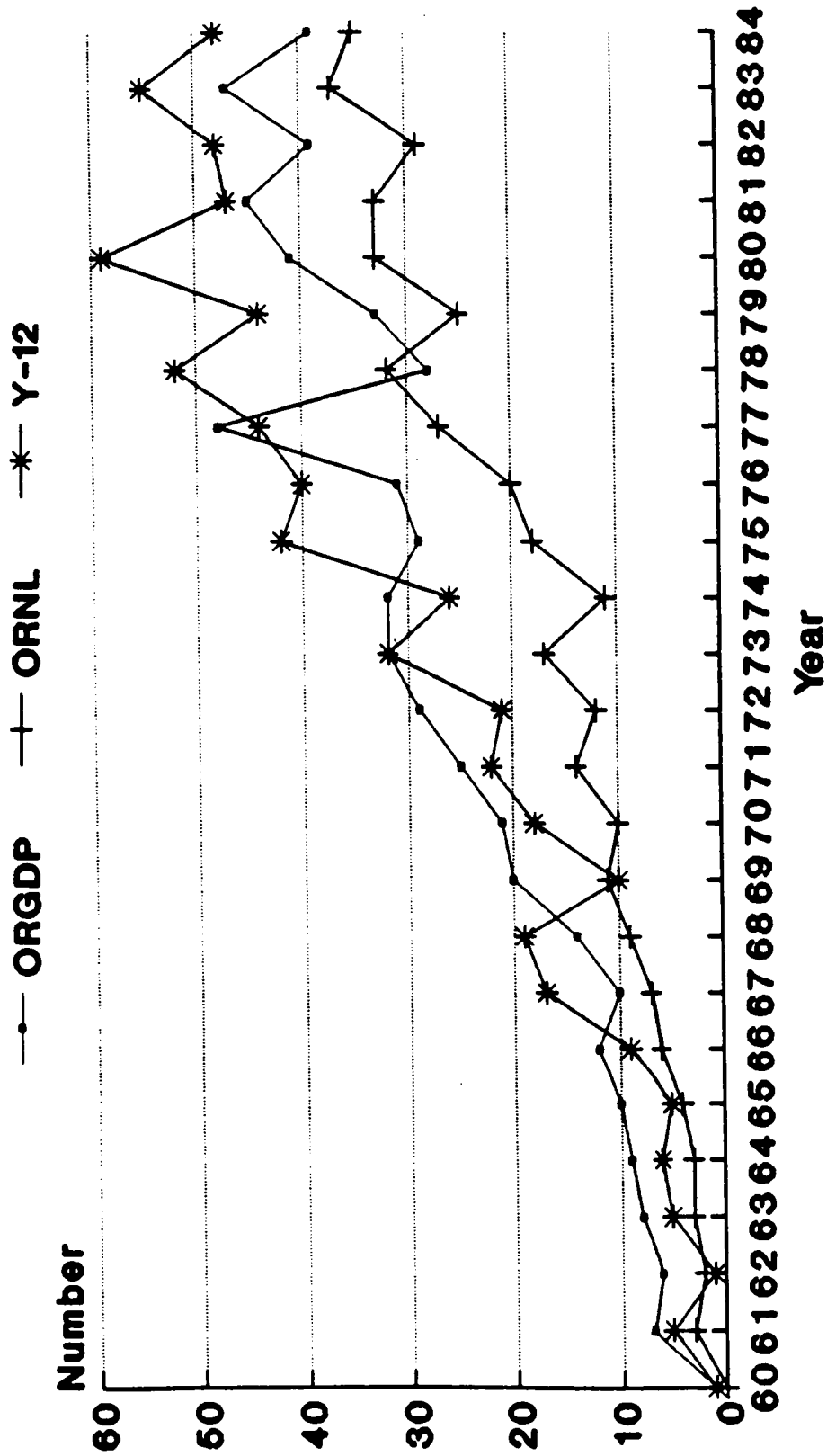
The occupational history obtained from the work history records at ORNL, Y-12, and ORGDP contained information for all jobs held from date of first employment until December 31, 1979. Each job history included dates worked, job title, department number, and pay code. For this study, jobs held for the last 12 months of full-time employment were

Table 8: Total Study Population by Facility and Year of Retirement

<u>Year Retired</u>	<u>ORNL</u>	<u>ORGDP</u>	<u>Y-12 Plant</u>	<u>Total Population</u>
1960	15	31	18	64
1961	32	169	39	240
1962	27	99	32	158
1963	24	56	34	114
1964	27	67	57	151
1965	39	35	87	161
1966	40	40	52	132
1967	35	29	53	117
1968	42	49	66	157
1969	53	39	78	170
1970	55	51	89	195
1971	90	55	106	251
1972	59	60	109	228
1973	127	94	155	376
1974	66	66	129	261
1975	84	102	154	340
1976	90	116	134	340
1977	91	111	167	369
1978	98	100	136	331
1979	57	104	128	289
Overall	1,148	1,473	1,823	4,444

Source: ORAU 1/31/90

Source: ORAU, 1/31/90



Frequency of Deaths by Year and Facility

Figure 2.

used to determine socioeconomic status. This was done because the Benefits Plans Office of UCC-ND based retirement pensions on the highest 3-year salary that was derived from the last 10 years of full-time employment. Historically the last year of full-time employment was the highest within the 10-year salary band.

Information concerning race, sex, birth date, date and cause of death (if dead), socioeconomic status (using plant pay code as a surrogate), job title, and demographics were taken from computerized data tapes maintained at ORAU. Each job title was assigned a job classification code (salaried or hourly) based on the last 12 months of employment. Hourly retirees were those persons who were paid on an hourly basis during their last 12 months of full time employment. Throughout the present study, the hourly group has been referred to "blue collar retirees." Persons who were paid on a monthly or weekly basis were combined to create a single comparison group of retirees. This group has been referred to as "white collar retirees" throughout the present study. When job assignments were completed, each cohort member had a socio-economic status (SES) category for the job he or she had during the last 12 months of full-time employment.

Based on the number of person-years and on the number of deaths that occurred in each group (ORNL, Y-12, and ORGDP), SMRs were computed for each group by using a computer program developed by Richard R. Monson (1974). Monson developed this method to analyze cohort data by using standard death rates (relative survival) and proportional mortalities based on cause-age-time-sex-race-specific data for the U.S. population from 1925 to 1984. The relative survival computer program consisted of 14 steps.

This researcher utilized Monson's program to calculate the expected mortality for the DOE-Oak Ridge retired population by using U.S. mortality rates from 1925 to 1982 as the standard. Mortality rates were assembled by for 57 causes of death (23 causes of cancers and

34 categories of other causes) for white males, white females, non-white males, and non-white females. Information regarding sex, race, age at entry, year of entry, years of survival, status at end of study (live, dead, or lost to follow-up) and cause of death (if dead) were provided for each member of the study cohort. Once these data were gathered, the 14 relative survival steps described below were employed:

1. The death rate matrix was read.
2. The age-year-of-entry distribution of the study cohort was determined in 5-year groupings using the successive age-bands of 50-54, 55-59, 60-64, 65-69, 70-74, 75-79, 80-84, and 85 and older.
3. The age-time specific person-years of the study was calculated. It should be noted that persons lost to follow-up were assumed to be alive through the date of the last observation; their person-years were terminated on the date of loss to follow-up.
4. The age-time distribution of the observed deaths was determined by:

$$\text{observed rates} = \frac{\text{observed deaths}}{\text{persons-years of survival}}$$

5. The age-time-specific expected deaths were calculated by multiplying age-time-specific standard death rates (derived from the ICD8 cause-of-death codes) by the age-time-specific person-years of follow-up.
6. Standard mortality ratios (SMRs) were calculated by:

$$\text{SMR} = \frac{\text{observed deaths}}{\text{expected deaths}}$$

7. The probability that the observed number of deaths would differ significantly from expected number of deaths was calculated using the modified Mantel-

Haenszel (Chi-Square) procedure. The confidence interval for each SMR was calculated, and its deviation from 1.00 was tested by assuming a Poisson distribution for the observed deaths and by using a one-tailed test of significance and an alpha level of 0.05 (when the observed or expected number of deaths was less than 5.00).

8. The relative survival life table was calculated by using the standard errors according to the method of Greenwood (1926). This method calculates the following numbers for each year of survival:
 - A. LX - Number starting each interval
 - B. WX - Number of live withdrawals
 - C. UX - Number lost to follow-up
 - D. OBS (DX) - Observed deaths
 - E. EXP (DX) - Expected deaths
 - F. OBS/EXP - Observed/expected ratio
 - G. SURV - Crude interval survival (i to $i + 1$)
 - H. RSR - Relative interval survival
 - I. SERSR - Standard error of RSR
 - J. CSURV - Crude cumulative survival (0 to $i + 1$)
 - K. CRSR - Relative cumulative survival
 - L. SECRSR - Standard error of CRSR
- 9-11. These steps were similar to steps 4-6, except that the person-years for each person were distributed horizontally according to age of entry into the cohort.

- 12-14. Person-years were distributed horizontally according to year of entry into the cohort. These steps were similar to steps 9-11.

SMRs were used as a statistical parameter for comparing the number of observed deaths to the number of expected deaths. The expected deaths were derived from a certain comparison population, such as the retirees of Y-12, by taking into consideration age, sex, employment duration, and calendar-time. The interpretation of SMRs was based on whether such ratios were significantly different from 1.00. Age-adjusted SMRs were used as a weighted average for all age-specific mortality ratios, with the weighing factor being derived from the age structure of the study population. Comparison of two age-adjusted SMRs was performed under the following conditions:

1. The age-specific mortality ratios within each population were similar across all age groups.
2. The similarity of the age distribution of the two groups was examined in terms of person-year distribution.

For the present study, person-years were accumulated from the date of termination (rather than the date on which employment began), through the date of death, loss to follow-up, or the end of the study, whichever was earlier. This constraint resulted in a conservative estimate of expected mortality.

The deaths recorded for the study population were grouped by calendar-time and 5-year-age-of-death intervals for ages 50-84, inclusive, and for the following ICD8 categories:

All causes (Code numbers 001-998)

1. Cancers (140-209)
2. Diabetes (250)
3. Cardiovascular diseases (390-413)

4. Cerebrovascular diseases (430-438)
5. All respiratory diseases (460-519)
6. Diseases of the digestive system (520-577)
7. Cirrhosis of the liver (571)
8. Genito-urinary diseases (580-629)
9. Accidents (950-959)
10. Suicide (950-959)

ICD8 codes 140-629 (items 1-8) are categories of disease traditionally associated with the HWE (Cragle, et al., 1988) and have been the leading causes of death in the U.S. population since 1950 (DDHS, 1988). Although accidents and suicide are not literally associated with occupational exposures, they have consistently ranked in the leading causes of death in persons 45 years of age and older in the U.S. since 1950 and were included as study variables. These ten selected causes of death provided a solid foundation for the comprehensive investigation of the study cohort.

Statistical significance was determined by comparing the observed number of deaths with the number of deaths expected in the comparison population. The assumption was made that the distribution of the difference would be Gaussian (normally distributed). This was expressed by the following formulas:

$$Z = \frac{O-E}{S} \text{ where}$$

$$E = \pi_i \text{, and}$$

$$S = \pi_i (1-\pi_i)$$

This technique resulted in statistical significance of smaller variations than if one had assumed the distribution to be Poisson and $S = E$.

Summary

In this chapter the study cohort was identified and the methods for obtaining the cohort were discussed. Tests of significance of difference included Chi-Square; SMRs; the "t test"; and various measures of association. The 0.05 level of significance was used in all hypothesis tests.

CHAPTER IV

RESULTS AND DISCUSSION

This chapter reports the results of the study. A discussion of the vital status and the cause of death determination will come first. Next, using the U.S. population as a standard, the overall statistical evaluation of standard mortality ratios (SMRs) for white salaried male retirees from each facility under investigation are described, followed by a similar comparison for white hourly male retirees. The analysis continues with a statistical evaluation of SMRs from a pooled salaried male group using the U.S. population as a comparison standard. A similar analysis is presented for a pooled hourly male population. Finally, the pooled salaried male population was used as a standard to statistically evaluate SMRs of the pooled hourly cohort. The aforementioned comparisons and statistical evaluations were replicated for female retirees from each of the facilities being studied. A detailed discussion section follows the results section of this study.

Vital Status Ascertainment and Cause of Death Determination

In this study the largest retired population, both in the number of retirees and in the total number of person-years, was found at the Y-12 Plant (Y-12). Table 9 provides a summary of the basic characteristics and vital status of the total study population by facility.

The percentage of retirees with unknown vital status was lowest (0.07%) in the combined hourly and salaried Oak Ridge National Laboratory (ORNL) group, while it was highest (0.52%) in the combined hourly and salaried Oak Ridge Gaseous Diffusion (ORGDP)

TABLE 9

Basic Characteristics of the Study Populations of Retired White Males from the Oak Ridge National Laboratory (ORNL), the Oak Ridge Gaseous Diffusion Plant (ORGDP), and the Oak Ridge Y-12 Plant (Y-12).

	ORNL	ORGDP	Y-12
Number of Retirees	1,029	1,330	1,698
Follow-Up Period	1960-1984	1960-1984	1960-1984
Person-Years	10,011.3	13,622.5	15,835.1
Average Follow-Up	10 years	10 years	9 years
Number Alive	643	726	1,034
Number Dead	384	582	654
(with Certificates)	(382)	(575)	(651)
Unknown Vital Status	2	22	10

group. Death certificate retrieval was most complete (100%) for hourly females; however, the other groups in the cohort also had high vital status ascertainment (e.g., hourly males, 99.5%; salaried males, 99.7%; and salaried females, 99.9%). Vital statistics for the entire cohort and for each retirement type are displayed in Table 10.

Table 11 provides a listing of the total number of deaths in the study population by year and by facility for the years 1960 through 1984. The pattern in which these deaths occurred by year and by facility is shown in Figure 2. The highest number of deaths for each plant site occurred in different years (ORNL, 122 deaths in 1983; ORGDP, 158 deaths in 1977; and Y-12, 169 deaths in 1980).

The results of this study also have yielded a sporadic pattern of retirement at the Oak Ridge facilities for the years 1960 through 1979. The retirement pattern is shown in Figure 3. No association was found in this study between year of retirement and year of peak number of deaths at any plant. Other than a plant's offering some type of incentive for early retirement, no other clear explanation for the peak death years could be determined. Figure 4 summarizes vital status of the entire cohort by facility and sex.

General Analyses of the Male Salaried Cohort by Facility

The initial phase of this study involved the investigation of all and selected causes of death among salaried male retirees at ORNL, ORGDP, and Y-12. As hypothesized in Chapter I, it was expected that no differences would be found in the survivorship and mortality experience of male salaried retirees at the Oak Ridge Department of Energy (DOE) facilities when they are compared to the U.S. population for all causes, all respiratory diseases, diabetes, diseases of the digestive system, cirrhosis of the liver, genito-urinary diseases, accidents, suicide, and diseases of the circulatory system (i.e., cardiovascular and

TABLE 10

Vital Status of Study Population by Facility, Pay Code, and Sex Through December 31, 1984.

Facility	Vital Status	Sex/PayCode	Frequency	Percentage of Total Study Population
ORNL	Alive	Male	643	14.5
			Hourly 239	5.4
			Weekly 95	2.1
			Monthly 309	7.0
		Female	101	2.3
			Hourly 2	0.01
			Weekly 85	2.0
			Monthly 14	0.3
Y-12 Plant	Alive	Male	1034	23.3
			Hourly 723	16.3
			Weekly 58	1.3
			Monthly 253	5.7
		Female	102	2.3
			Hourly 46	1.0
			Weekly 53	1.2
			Monthly 3	0.1
ORGDP	Alive	Male	726	16.3
			Hourly 409	9.2
			Weekly 69	1.6
			Monthly 248	5.5
		Female	108	2.4
			Hourly 12	0.3
			Weekly 93	2.1
			Monthly 3	0.06
Totals	Alive	Male/Female	2403+311=2,714	54.1+7.0=61.1

Continued on next page

TABLE 10 (continued)

Vital Status of Study Population by Facility, Pay Code, and Sex Through December 31, 1984.

Facility	Vital Status	Sex/PayCode	Frequency	Percentage of Total Study Population
ORNL	Dead	Male	384	8.6
		Hourly	210	4.7
		Weekly	46	1.0
		Monthly	128	2.9
		Female	17	0.4
		Hourly	2	0.05
		Weekly	12	0.3
		Monthly	3	0.07
Y-12	Dead	Male	654	14.7
		Hourly	482	10.9
		Weekly	41	0.9
		Monthly	131	2.9
		Female	22	0.5
		Hourly	9	0.2
		Weekly	13	0.3
		Monthly	0	-
ORGDP	Dead	Male	582	13.1
		Hourly	391	8.8
		Weekly	46	1.0
		Monthly	145	3.3
		Female	34	0.8
		Hourly	6	0.1
		Weekly	27	0.6
		Monthly	1	0.02
Total	Dead	Male/Female	1620+73=1,693	36.5+1.6=38.1

Continued on next page

TABLE 10 (continued)

Vital Status of Study Population by Facility, Pay Code, and Sex Through December 31, 1984.

Facility	Vital Status	Sex/PayCode	Frequency	Percentage of Total Study Population
ORNL	Unknown	Male	2	0.05
			Hourly	-
			Weekly	-
			Monthly	0.5
		Female	1	0.02
			Hourly	-
			Weekly	0.02
			Monthly	-
Y-12	Unknown	Male	10	0.2
			Hourly	9
			Weekly	-
			Monthly	0.2
		Female	1	0.02
			Hourly	-
			Weekly	0.02
			Monthly	-
ORGDP	Unknown	Male	22	0.5
			Hourly	13
			Weekly	2
			Monthly	0.2
		Female	1	0.02
			Hourly	-
			Weekly	0.02
			Monthly	-
Total	Unknown	Male/Female	34+3=37	0.76+0.07=0.8
Total Cohort		Male/Female	4,057+387=4,444	913+87=100

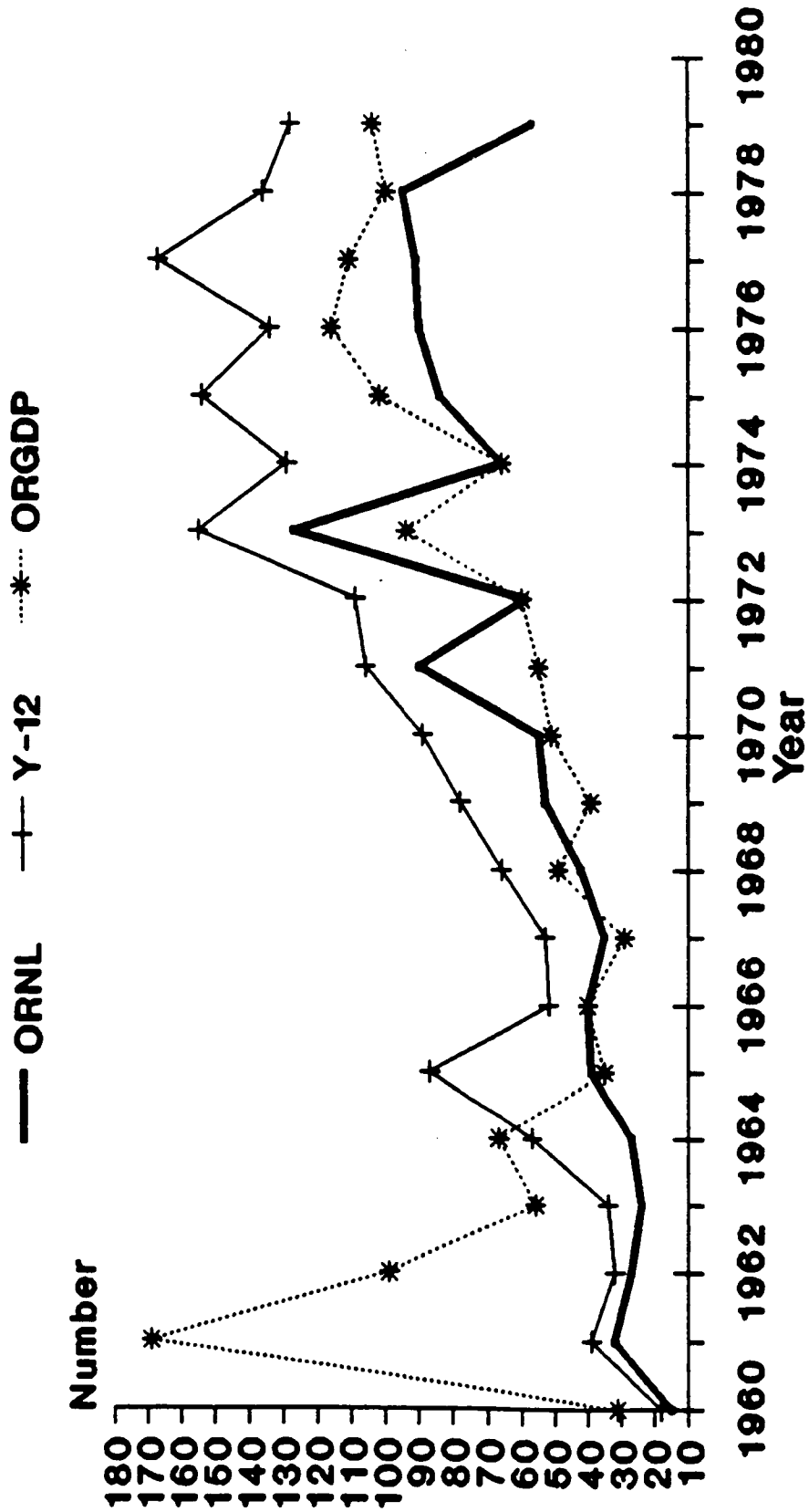
TABLE 11

Number of Deaths in the Study Population by Facility and Year of Death

Facility	1960	1961	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972
ORNL	0	3	2	3	3	4	6	7	9	11	10	14	12
ORGDP	1	7	6	8	9	10	12	10	14	20	21	25	29
Y-12	1	5	1	5	6	5	9	17	19	10	18	22	21
Total	2	15	9	16	18	19	27	34	42	41	49	61	62
Facility	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	Total
ORNL	17	11	18	20	27	32	25	33	33	29	37	35	401
ORGDP	32	32	29	31	48	28	33	41	45	39	47	39	616
Y-12	32	26	42	40	44	52	44	59	47	48	55	48	676
Total	81	69	89	91	119	112	102	133	125	116	139	122	1693

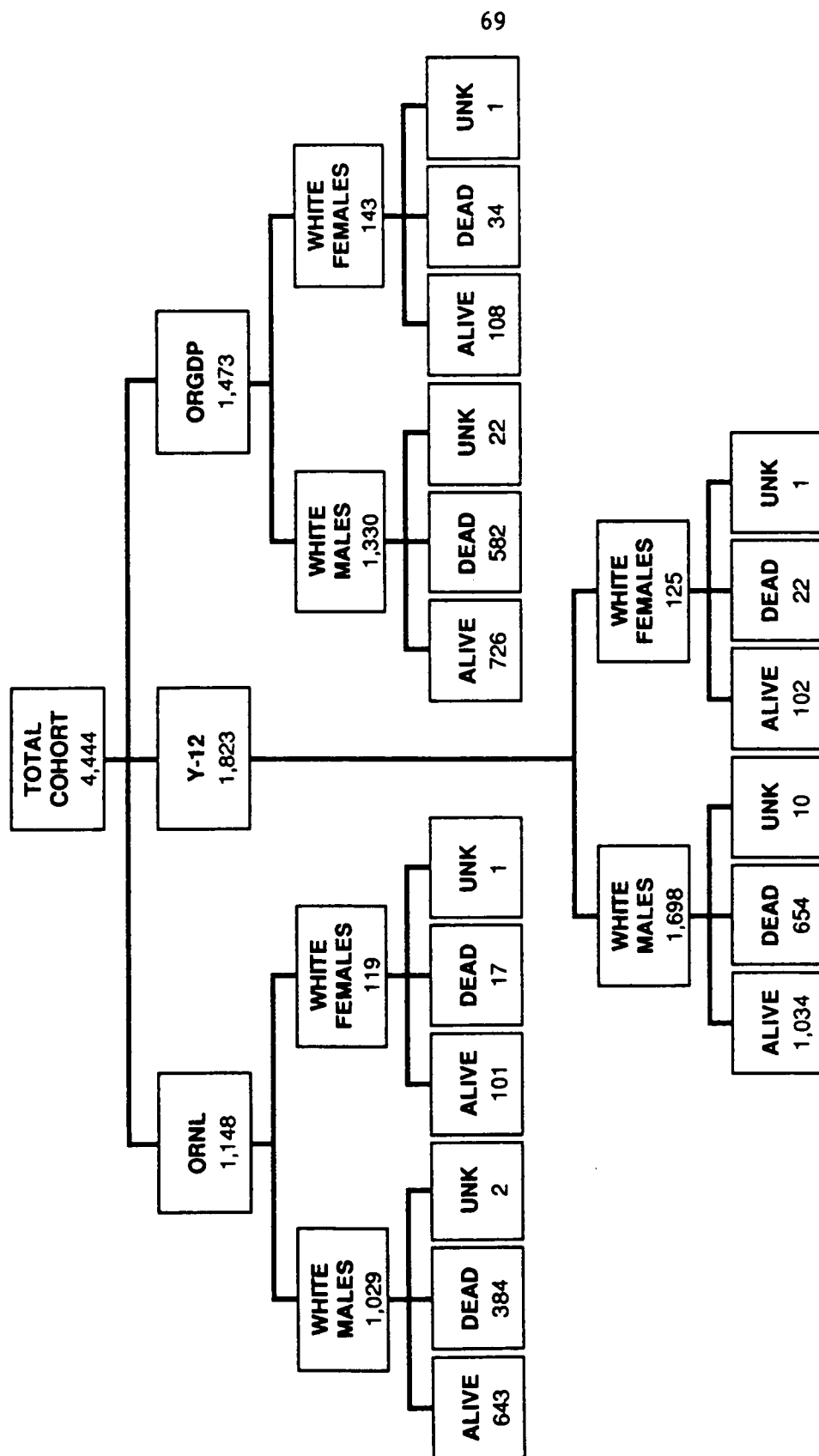
Table includes both male and female deaths

SOURCE: ORAU, 1/31/90



Retirement Patterns by Facility
DOE, Oak Ridge Facilities: 1960-1979

Figure 3.



Cohort Vital Status and Distribution by Facility and Sex

Figure 4

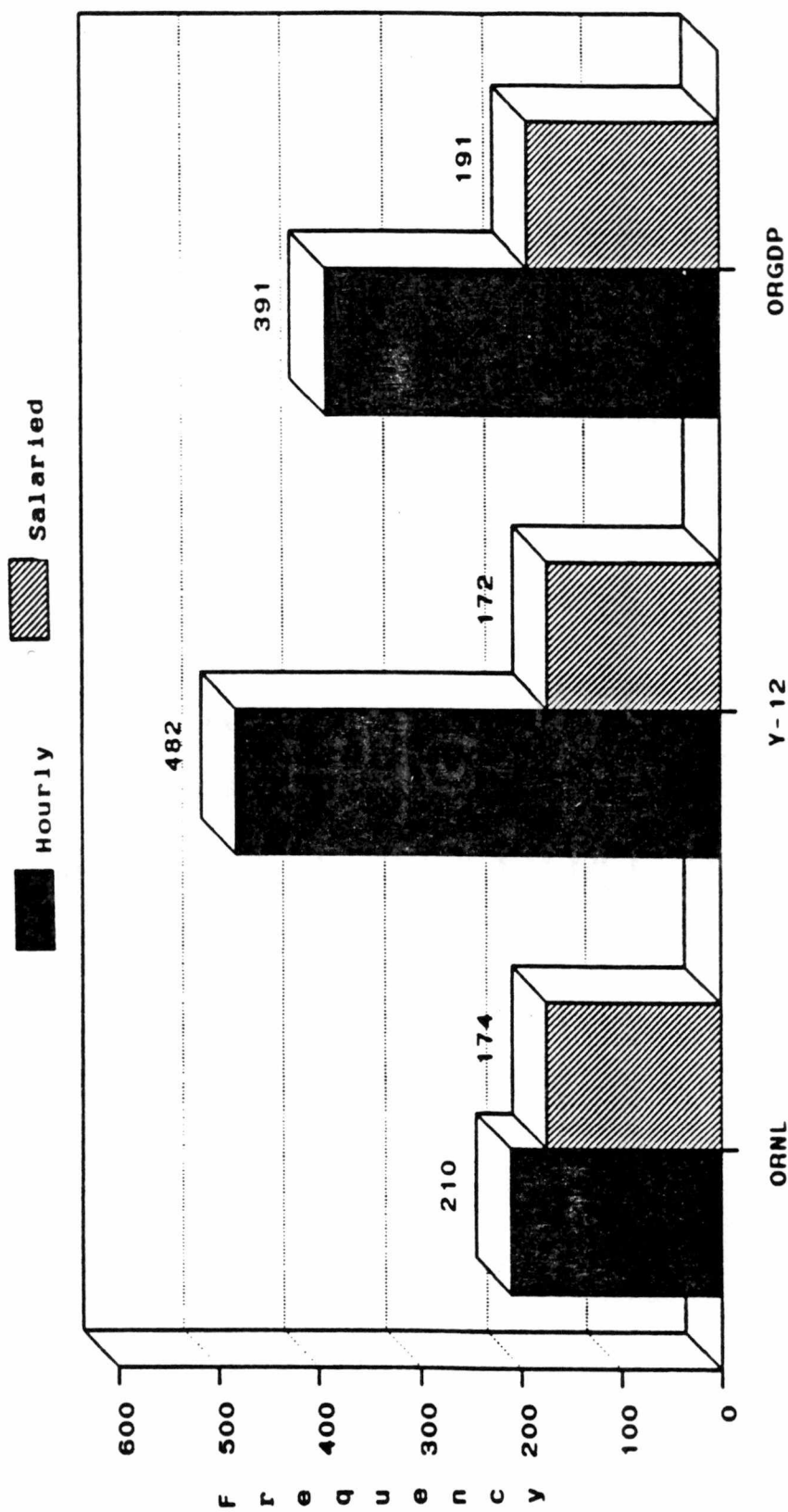
cerebrovascular diseases combined). Conversely, it was also hypothesized that survival and mortality due to all cancers combined in the salaried cohort would be elevated when compared to the U.S. general population.

Of the ten selected causes of death for the salaried retirees, SMR discussion was confined to diseases of the circulatory system (267 observed) and all cancers (124 observed), since they comprised 73% of the all causes (537 observed) category in the cohort. The total frequency of deaths by facility for the salaried groups is shown in Figure 5. The relative frequency of deaths between the salaried and hourly groups at each plant was generally reflective of the distribution of retirees (see Table 11). The male salaried group contained 1,581 retirees (ORNL, 580; Y-12, 484; and ORGDP, 517), with 537 observed deaths. Death certificates were retrieved for 534 (99.4%) of these observed deaths, and 12 (0.8%) were lost to follow-up.

In Table 12 the SMRs are presented according to age at entrance into follow-up. Table 12 also provides SMRs for age-specific mortality from all and selected causes of death and number of person-years of observation for the salaried retiree data by 5-year age-groups at each facility. For the middle age-groups (i.e., 55-79 years), number of person-years and observed deaths were large enough to provide greater statistical reliability than the lower or upper age-groups. However, there were substantially greater person-years in the group aged 50-54 than in the 80-85 and older age-groups.

In addition, for each 5-year age interval, the number of person-years was distributed in a time-dependent manner, such that a retiree in the 65-69 age-band contributed person-years to the three categories through which he passed until he was eligible to enter the 65-69 age-band. As a result, the male salaried group's sample size (15,048.5 person-years for the total male salaried cohort = 5,540.6 person-years from the ORNL group + 5,021.1 person-

Source: ORAU, 1/31/90



Frequency of Deaths: All Sites
by Pay Status for White Males: 1960-1984

Figure 5.

TABLE 12

Standardized Mortality Ratios (SMR) for All Causes of Death by Five-Year Age Groups for Salaried Males of ORNL, ORGDP, and the Y-12 Plant.

		*All Causes (001-998)										Y-12	
		ORNL					ORGDP						
O / E ⁺		SMR	95% C.I. ⁺⁺	0 / E	SMR	95% C.I. ⁺⁺	0 / E	SMR	95% C.I. ⁺⁺	50-54	0 / E ⁺	SMR	95% C.I. ⁺⁺
50-54	5	2.29	2.17	0.71-5.00	50-54	4	1.67	2.35	0.64-5.91	50-54	0	0.93	-
55-59	9	10.78	0.83	0.38-1.57	55-59	11	9.46	1.16	0.58-2.07	55-59	11	6.00	1.83 0.91-3.26
60-64	36	29.47	1.22	0.86-1.69	60-64	35	26.01	1.35	0.94-1.87	60-64	39	21.80	1.79 **1.27-2.44
65-69	60	67.17	0.89	0.68-1.50	65-69	55	61.53	0.89	0.67-1.16	65-69	47	60.70	0.77 0.57-1.03
70-74	38	51.88	0.73	0.52-1.01	70-74	42	51.14	0.82	0.59-1.10	70-74	44	49.15	0.90 0.65-1.20
75-79	17	24.29	0.70	0.41-1.12	75-79	29	25.75	1.12	0.75-1.62	75-79	22	24.79	0.89 0.55-1.34
80-84	7	7.58	0.92	0.37-1.88	80-84	11	10.77	1.02	0.51-1.82	80-84	8	7.78	1.03 0.44-2.01
85+	2	0.95	2.09	0.24-6.39	85+	4	2.89	1.38	0.37-3.42	85+	1	1.40	0.71 -
Overall	174	194.41	0.90	0.77-1.04	191	189.22	1.01	0.87-1.16		172	172.55	1.00	0.85-1.16

*ICD-8, International Classification of Diseases, Eighth Revision.

⁺Based on rates for U.S. white males, adjusted for age and calendar year.

⁺⁺Fisher's exact confidence limits.

^{**}Statistically significant (P<0.05).

-Less than two deaths observed.

Continued on next page

TABLE 12 (continued)

Standardized Mortality Ratios (SMR) for All Cancers by Five-Year Age Groups for Salaried Males of ORNL, ORGDP, and the Y-12 Plant.

		*All Cancers (140-209)				Y-12			
		ORNL		ORGDP		ORNL		ORGDP	
O / E [†]		SMR	95% C.I. ^{††}	0 / E	SMR	95% C.I. ^{††}	0 / E	SMR	95% C.I. ^{††}
50-54	2	0.50	4.00	0.45-12.21	50-54	1	0.36	2.70	-
55-59	1	2.71	0.37	-	55-59	3	2.31	1.30	0.26-3.56
60-64	6	7.88	0.76	0.29-1.63	60-64	5	6.69	0.75	0.24-1.71
65-69	17	17.41	0.98	0.57-1.56	65-69	9	15.56	0.58	0.26-1.09
70-74	8	12.86	0.62	0.27-1.23	70-74	10	12.36	0.81	0.39-1.48
75-79	2	5.33	0.38	0.04-1.14	75-79	5	5.50	0.91	0.29-2.08
80-84	0	1.40	-	-	80-84	3	1.95	1.54	0.31-4.22
85+	1	0.12	8.33	-	85+	0	0.38	-	-
Overall	37	48.21	0.77	0.54-1.06	36	45.11	0.80	0.55-1.11	
							51	41.94	1.22 0.91-1.60

*ICD-8, International Classification of Diseases, Eighth Revision.

[†]Based on rates for U.S. white males, adjusted for age and calendar year.

^{††}Fisher's exact confidence limits.

**Statistically significant (P<0.05).

-Less than two deaths observed.

Continued on next page

TABLE 12 (continued)

Standardized Mortality Ratios (SMR) for Diseases of the Circulatory System by Five-Year Age Groups for Salaried Males of ORNL, ORGDP, and the Y-12 Plant.

*Circulatory Diseases (410-458)											
ORNL				ORGDP				Y-12			
O / E ⁺	SMR	95% C.I. ⁺⁺	0 / E	SMR	95% C.I. ⁺⁺	0 / E	SMR	95% C.I. ⁺⁺	0 / E	SMR	95% C.I. ⁺⁺
50-54 0	1.12	-	50-54 1	0.83	1.21	50-54 0	0.46	-	50-54 0	0.46	-
55-59 7	5.39	1.30 0.52-2.64	55-59 7	4.79	1.46 0.59-2.97	55-59 3	3.02	1.00 0.20-2.72	55-59 3	3.02	1.00 0.20-2.72
60-64 16	14.95	1.07 0.61-1.73	60-64 19	13.45	1.41 0.85-2.20	60-64 14	11.17	1.25 0.69-2.10	60-64 14	11.17	1.25 0.69-2.10
65-69 32	35.33	0.91 0.62-1.28	65-69 29	32.78	0.88 0.59-1.27	65-69 23	32.10	0.72 0.45-1.07	65-69 23	32.10	0.72 0.45-1.07
70-74 21	27.85	0.75 0.47-1.15	70-74 24	27.85	0.86 0.55-1.28	70-74 20	26.64	0.75 0.46-1.16	70-74 20	26.64	0.75 0.46-1.16
75-79 11	13.52	0.82 0.41-1.44	75-79 18	14.58	1.23 0.73-1.95	75-79 6	13.86	0.43 **0.16-0.93 ⁷⁴	75-79 6	13.86	0.43 **0.16-0.93 ⁷⁴
80-84 4	4.40	0.91 0.25-2.25	80-84 6	6.35	0.94 0.35-2.03	80-84 1	4.57	0.22 -	80-84 1	4.57	0.22 -
85+ 1	0.59	1.67 -	85+ 3	1.79	1.67 0.34-1.67	85+ 1	0.89	1.11 -	85+ 1	0.89	1.11 -
Overall 92	103.15	0.89 0.72-1.09	107	102.42	1.05 0.86-1.26	68	92.71	0.73 **0.57-0.93	68	92.71	0.73 **0.57-0.93

*ICD-8, International Classification of Diseases, Eighth Revision.

⁺Based on rates for U.S. white males, adjusted for age and calendar year.

⁺⁺Fisher's exact confidence limits.

**Statistically significant (P<0.05).

-Less than two deaths observed.

Continued on next page

TABLE 12 (continued)

Person Years by Five-Year Age Groups for Salaried Retirees of ORNL, ORGDP, and the Y-12 Plant.

Age	ORNL	ORGDP	Y-12	Total Person Years
50-54	222.0	159.9	90.8	472.7
55-59	699.1	600.1	382.5	1681.7
60-64	1278.9	1094.3	927.4	3300.6
65-69	1926.6	1733.1	1727.8	5387.5
70-74	1018.3	986.9	953.6	2958.8
75-79	322.3	335.1	327.6	985.0
80-84	68.3	96.1	69.6	234.0
85+	5.1	15.6	7.5	28.2
TOTALS	5540.6	5021.1	4486.8	15048.5

years from the ORGDP group + 4,486.8 person-years from the Y-12 group), coupled with an average observation period of 29 years, was adequate to produce statistically interpretable data.

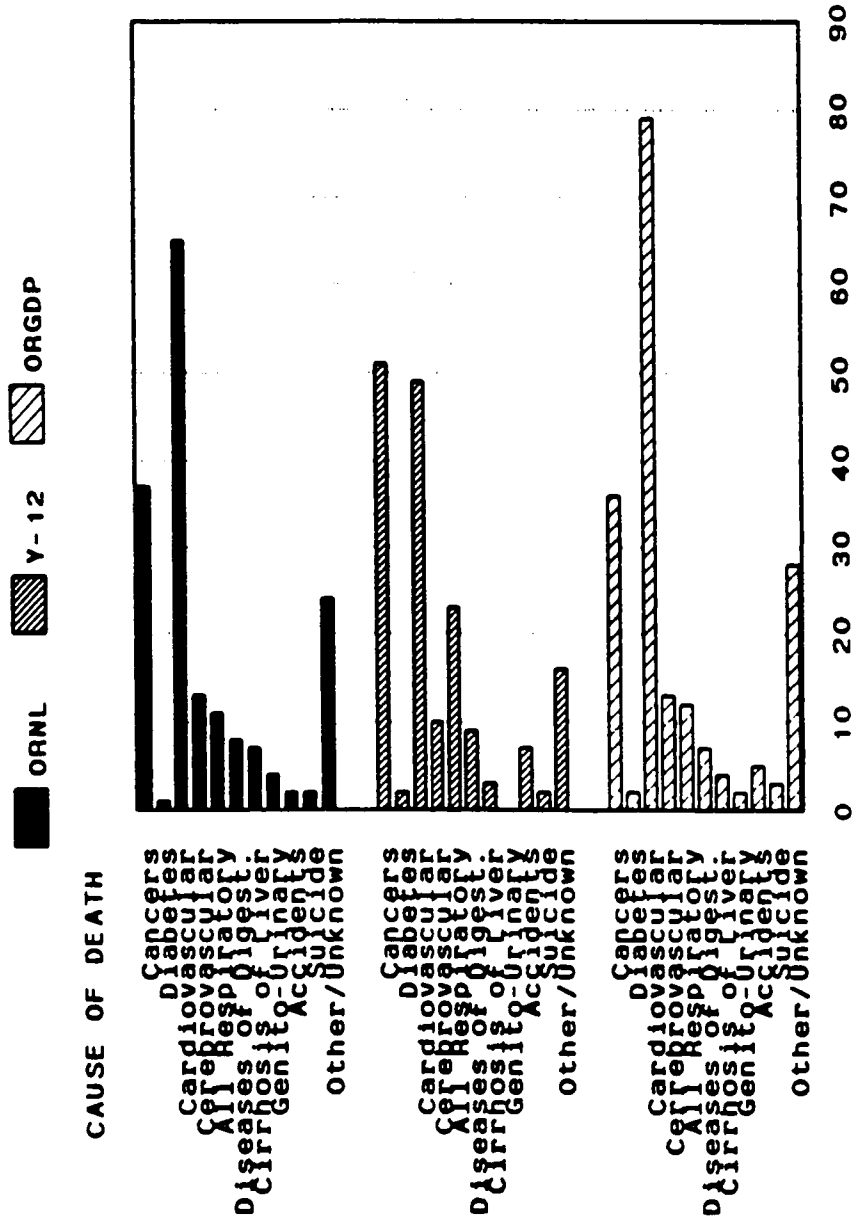
Table 12 also shows the cause-specific SMRs for salaried retirees by facility relative to the U.S. white male population for the years 1960 through 1984. The SMR of 0.99 (172 observed versus 172.6 expected and 191 observed versus 191.2 expected) for all causes of death was as expected for both the Y-12 and ORGDP white collar retirees. The SMR of 0.90 (174 observed versus 194.4 expected) for all causes was also as expected for ORNL white collar retirees. The deficit in mortality from all cancers (36 observed versus 45.5 expected) was the principal stabilizing factor for the overall mortality rate in the white male collar retiree group at ORGDP. All cancers (37 observed versus 48.2 expected) and diseases of the circulatory system (92 observed versus 103.15 expected) were the main contributors to the deficit in overall mortality for white collar retirees at ORNL. The data revealed, however, that diseases of the circulatory system (68 observed versus 92.71 expected) in the Y-12 white collar retired population were the primary reasons why the overall mortality remained as expected in this group.

As hypothesized, the overall health status of the retired salaried male population compared favorably with the general U.S. population for all and major causes of death. Some significantly elevated and age-specific SMRs may be of biological importance. Figure 6 provides an enumerated summary of selected causes of death in the salaried group by facility.

Age-Specific SMR Analyses of the Male Salaried Cohort by Facility

Further analysis was performed using each facility to investigate age-specific SMRs for all and selected causes of death. Table 12 displays all causes, all cancers, and cardiovascular disease SMRs for the salaried male retirees by 5-year age-groups for ages 50-85, and older.

Source: ORAU, 1/31/90



Enumeration of Cause of Death: All Sites
for Salaried White Males: 1960-1984

Figure 6.

At ORNL age-specific SMRs were elevated, but were not statistically significant, for all causes combined for the age-bands 50-54 (SMR = 2.71; 95% C.I. = 0.71, 5.00), 60-64 (SMR = 1.22; 95% C.I. = 0.86, 1.69), and 85 and older (SMR = 2.09; 95% C.I. = 0.24, 6.39). The wide confidence interval shown in the 50-54 and 85 and older age-bands was based on two observed and 0.95 expected deaths, respectively. At ORNL for all age-bands, there were no significant differences in mortality rates when compared to the U.S. population.

Similarly, for all causes at ORGDP, the age-specific SMRs were elevated over age-bands 50-54 (SMR = 2.35; 95% C.I. = 0.64, 5.91), 55-59 (SMR = 1.16; 95% C.I. = 0.58, 2.07), 60-64 (SMR = 1.35; 95% C.I. = 0.94, 1.87), and 85 and older (SMR = 1.38; 95% C.I. = 0.37, 3.42). However, no instances of significantly elevated or decreased deaths from all causes were noted for these groups.

Slight elevations in age-specific SMRs for all causes were also found for the Y-12 salaried male retirees for age-bands 54-59 (SMR = 1.83; 95% C.I. = 0.91, 3.26) and 80-84 (SMR = 1.03; 95% C.I. = 0.44, 2.01). There were no deaths observed in the age-band 50-54 in the Y-12 Plant salaried retired group. The number of deaths due to all causes combined in these age-band was not significantly different from the U.S. population. A statistically significant increase in the number of deaths was noted among the Y-12 salaried males for all causes combined in the age-band 60-64 (SMR = 1.79; 95% C.I. = 1.27, 2.44). This significant excess in mortality was based on 39 observed deaths versus 21.8 expected deaths. Because of the methodology of this study, retirees dying in this age-band could conceivably be those who had left the Oak Ridge facilities prior to the normal retirement age of 65.

When all three plants were examined together to look for common age-specific patterns, a deficit SMR trend began at the age-band 65-69 at each facility and continued through the age-band 70-74. The deficit trend was displayed longest in the ORNL salaried

group, beginning at age-band 65-69 and continuing to age-band 80-84 before the SMRs became elevated in the 85 and older age-group. The deficit SMR trend was shortest for the ORGDP salaried group, beginning at age-band 65-69 and ending at age-band 70-74. The Y-12 salaried group displayed SMR deficits similar to those of the ORNL group; however, at the 80-84 age-band the SMR was as expected and a deficit SMR was exhibited for the 85 and older age-band. There were no statistically significant elevations or decrements from all causes of death in any of the salaried groups of retirees for any age-band above 60-64.

For all causes at each facility, there were fewer than expected observed deaths in the retired salaried groups. As shown in Table 12, the overall expected number was based on rates for U.S. white males (ORNL/SMR = 0.90, 95% C.I. = 0.77, 1.04; ORGDP/SMR = 1.01, 95% C.I. = 0.87, 1.16; Y-12/SMR = 1.00, 95% C.I. = 0.85, 1.16). Relative mortality deficits in age-bands 65-69 and 70-74 were the major contributors to the overall lowered mortality rate in the salaried cohort. These findings showed a high degree of consistency with the frequently reported "Healthy Worker Effect (HWE)" (Cragle, et al., 1988).

For all cancers combined at ORNL, the age-specific SMR (4.00) was elevated but was not statistically significant for the age-band 50-54 (95% C.I. = 0.45, 12.21). In addition, the wide confidence interval coupled with such a small number of deaths (2.00 observed versus 0.50 expected) made any interpretation of the finding questionable at best. The SMRs for all cancers in the ORNL salaried group for the age-bands 55-59, 60-64, 65-69, 70-74, and 75-79 varied between 0.37 and 0.98 for different age-groups, with an overall SMR of 0.77 (37 observed, 42.2 expected; 95% C.I. = 0.54, 1.06) for persons aged 50-85 and older. In these age-bands, no strong upward or downward trend was apparent. There were no mortality observations in the age-band 80-84; 1.4 deaths were expected. The SMR for age-band 85 and

older was elevated. However, this nonsignificant elevation ($SMR = 8.33$) was based on one observed death and 0.12 expected deaths.

For all cancers at ORGDP, the age-specific SMRs were elevated for the age-bands 50-54 and 55-59. In these age-bands SMRs were based on one observed death versus 0.36 expected deaths and three observed deaths versus 2.31 expected deaths, respectively. None of these deaths was statistically significant. The subsequent age-bands of 60-64, 65-69, 70-74, and 75-79 had an overall SMR of 0.79 (36.0 observed, 45.5 expected; 75% C.I. = 0.55, 1.09), with SMRs that varied between 0.58 and 0.91 for the ORGDP salaried group. No strong upward or downward trend was apparent. The SMR for persons aged 80-84 (3.00 observed, 1.95 expected; 95% C.I. = 0.31, 4.22) was slightly elevated. There were no mortality observations in the 85 and older age-band, and only 0.38 deaths were expected in this group. There were no statistically significant elevations or decrements in any age-band for the ORGDP salaried group.

The Y-12 salaried group's age-specific SMR for all cancers combined was nonsignificantly elevated for the age-band 55-59 ($SMR = 2.67$; 95% C.I. = 0.73, 6.67). The SMR for all cancers in the age-band 55-59 was greater than, but not statistically different from, 1.00. However, a statistically significant increase in the number of cancer deaths was noted in the age-band 60-64 ($SMR = 2.11$; 95% C.I. = 1.09, 3.66) for the Y-12 salaried group. The significant excess in mortality for all cancers combined in this age-band was based on 12.00 observed deaths versus 5.71 expected deaths. Because of the methodology used in this study, retirees who died in this age-band were those who had left the Oak Ridge facilities prior to the normal retirement age of 65. No statistically significant deviations from the expected values were observed in the Y-12 salaried group for all cancers in age-bands 65-69,

70-74, 75-79, and 80-84. There were no observations in cancer mortality for the age-band 85 and older.

For all cancers at ORNL and ORGDP, there were fewer than expected overall observed deaths in the retired salaried groups. The overall deficit findings at ORNL (SMR = 0.77, 95% C.I. = 0.54, 1.06) and ORGDP (SMR = 0.80, 95% C.I. = 0.55, 1.11) were based on rates for white American males (see Table 12). Relative mortality deficits for ORNL in age-bands 50-59 and 70-85, and older, and for ORGDP in age-bands 50-54 and 60-79 were the major contributors to the overall lowered mortality levels in those two populations. These findings demonstrate a high degree of consistency with the frequently reported HWE (Checkoway, et al., 1985). However, in the Y-12 retired salaried group the overall number of deaths observed from all causes combined was essentially the same as the number of deaths expected (SMR = 1.00). As shown in Table 12, the overall excess in cancer mortality was principally caused by an elevated number of deaths in the 55-59 and 60-64 age-bands. The elevation in the number of cancer deaths in these age-bands was also the key contributor for the HWE not being seen in the overall all causes combined category for the retired Y-12 male salaried population.

Cardiovascular (ICD8 = 390-413) and cerebrovascular diseases (ICD8 = 430-438) were combined to create a new study variable: diseases of the circulatory system (ICD8 = 390-458). The use of this new variable increased the sample size within the facilities under investigation when they were compared to the U.S. population.

The mortality results for diseases of the circulatory system in the ORNL salaried male group showed the SMRs to be as expected for the age-bands 55-59 (SMR = 1.30; 95% C.I. = 0.52, 2.64) and 60-64 (SMR = 1.07; 95% C.I. = 0.61, 1.73). There were no mortality observations in the age-band 50-54. The proceeding age-bands 65-69 (SMR = 0.91; 95%

C.I. = 0.62, 1.28), 70-74 (SMR = 0.75; 95% C.I. = 0.47, 1.15), 75-79 (SMR = 0.82; 95% C.I. = 0.41, 1.44), and 80-84 (SMR = 0.91; 95% C.I. = 0.25, 2.25) had an overall SMR of 0.89 (92.00 observed, 103.15 expected) and contained SMRs that varied between 0.75 and 0.91 for the ORNL salaried group. Deficits were noted for each one of these ORNL age-bands; however, there was no strong upward or downward trend apparent. The SMR for persons 85 and older (one death observed, 0.59 deaths expected) was slightly elevated. There were no statistically significant elevations or decrements in any age-band for the ORNL salaried group.

The number of deaths due to diseases of the circulatory system in the ORGDP salaried group for the age-bands 50-54 (1.00 death observed, 0.85 deaths expected), 55-59 (SMR = 1.46; 95% C.I. = 0.59, 2.97), and 60-64 (SMR = 1.41; 95% C.I. = 0.85, 2.20) were slightly, but nonsignificantly, elevated. Relative mortality deficits were seen in age-bands 65-69 (SMR = 0.88; 95% C.I. = 0.59, 1.27) and 70-74 (SMR = 0.86; 95% C.I. = 0.55, 1.28). There were nonsignificant excesses in the number of deaths due to diseases of the circulatory system in age-bands 75-79 (SMR = 1.23; 95% C.I. = 0.73, 1.95) and 85 and older (95% C.I. = 0.37, 1.67) for the ORGDP salaried group. The SMR for age-band 80-84 (SMR = 1.67; 95% C.I. = 0.35, 2.03) was as expected.

At Y-12 there were no observations of mortality from diseases of the circulatory system for the salaried age-band 50-54. For age-bands 55-59 (SMR = 1.00; 95% C.I. = 0.20, 2.72) and 60-64 (SMR = 1.25; 95% C.I. = 0.69, 2.10) SMRs were as expected. A deficit trend was noted for the proceeding age-bands of 65-69 (SMR = 0.72; 95% C.I. = 0.45, 1.07), 70-74 (SMR = 0.75; 95% C.I. = 0.46, 1.16), and 80-84 (SMR = 0.22; 1.00 deaths observed versus 4.57 expected). A significant decrease was exhibited in the salaried age-group 75-79 at Y-12 (SMR = 0.43; 95% C.I. = 0.16, 0.93). The significant deficit in mortality from

circulatory diseases was based on 6.00 observed deaths versus 13.86 expected. The SMR for the age-band 85 and older was as expected (SMR = 1.11; 1.00 deaths observed versus 0.89 expected).

In general, the mortality experience of the salaried white male populations of ORNL and ORGDP for circulatory diseases was as expected when compared to a similar segment of the U.S. population. Usually, SMRs for circulatory diseases in working populations are usually less than 1.00 (Dupree, et al., 1987), but tend to approach or exceed 1.00 as a population ages. Accordingly, it was not very surprising to find the slightly elevated SMR (1.05) within the ORGDP salaried population. Unlike the ORGDP salaried male population, the overall SMR (0.73) for circulatory diseases in the Y-12 salaried male population was significantly less than 1.00.

No clear explanation could be ascertained for the significant deficit of mortality from circulatory diseases in the Y-12 salaried male population. Primarily, it was believed that the favorable mortality rates from circulatory diseases among salaried males across all sites is attributable to the selection of healthy salaried males at the date of first hire.

Generalizations Regarding the Mortality Experience of the Salaried Male Cohorts at the Three Separate Sites and Hypotheses Outcomes

As a result of the examination of all causes and the two broad selected causes of death at each DOE facility under investigation, the following generalizations were made regarding the male salaried groups' mortality experience when each facility was compared separately to the U.S. white male population:

ORNL

1. The ORNL salaried male group experienced mortality lower than the general U.S. population for all causes and diseases of the circulatory system between the

ages 65-84.

2. The ORNL salaried male group experienced mortality lower than the general U.S. population for all cancers between the ages 55-79.
3. No statistically significant excess in mortality was found in any retirement age-band for the ORNL salaried male group.
4. These findings were consistent with the previous reports of the HWE.

ORGDP

1. The ORGDP salaried male group experienced slight and nonstatistically significant excesses in mortality relative to the general U.S. population for all causes, all cancers, and diseases of the circulatory system between the ages 50-59.
2. The ORGDP salaried male group experienced mortality lower than the general U.S. population for all causes combined, all cancers combined, and diseases of the circulatory system between the ages 65-74. Once again, this finding was consistent with the HWE.
3. The overall mortality experience of the ORGDP salaried male cohort was as expected.

Y-12

1. When compared to the U.S. population, the salaried male group from Y-12 exhibited significantly elevated mortality for all causes combined and all cancers combined between the ages 60-64.
2. The salaried male group from Y-12 experienced mortality lower than the general U.S. population for all causes combined, all cancers combined, and

diseases of the circulatory system between the ages 65-69. The lower than expected mortality deficit trend continued in this group for all causes and diseases of the circulatory system for ages 70-79. These findings indicated the presence of a HWE.

3. The overall mortality experience of the Y-12 salaried male cohort was as expected.

These findings support null hypothesis-1 (there will be no differences in survivorship and mortality experience for white collar retirees of ORNL, ORGDP, or Y-12 when compared individually to the U.S. for all causes, diabetes, all respiratory diseases, diseases of the digestive system, cirrhosis of the liver, genito-urinary diseases, accidents, and suicide). As indicated in the data generated from the Mortality Analysis System (MAS), there is very strong evidence that overall death rates among the three white collar male groups were comparable and, in some age-specific cases, better than that of the general population. These findings support the postulation that the HWE continues into post retirement.

Further evidence relative to carry-over in the HWE is demonstrated by the rejection of alternative hypothesis-1 (excess in death rates will be seen for white collar male retirees of ORNL, ORGDP, and Y-12 when compared individually to the U.S. for all cancers and circulatory diseases [i.e., cardiovascular and cerebrovascular diseases combined]). Taking into consideration the very nature of the work at the DOE-Oak Ridge facilities and the potential for elevated hypertension, one would expect death rates from the aforementioned causes to be slightly higher than that of the general population. However, the rejection of alternative hypothesis-1 provides further evidence that the HWE was exhibited by the white collar male retirees following their separation from any one of the three government facilities under

investigation. Possible explanations for the lower-than-expected death rates in the white collar male cohort are discussed later in this chapter.

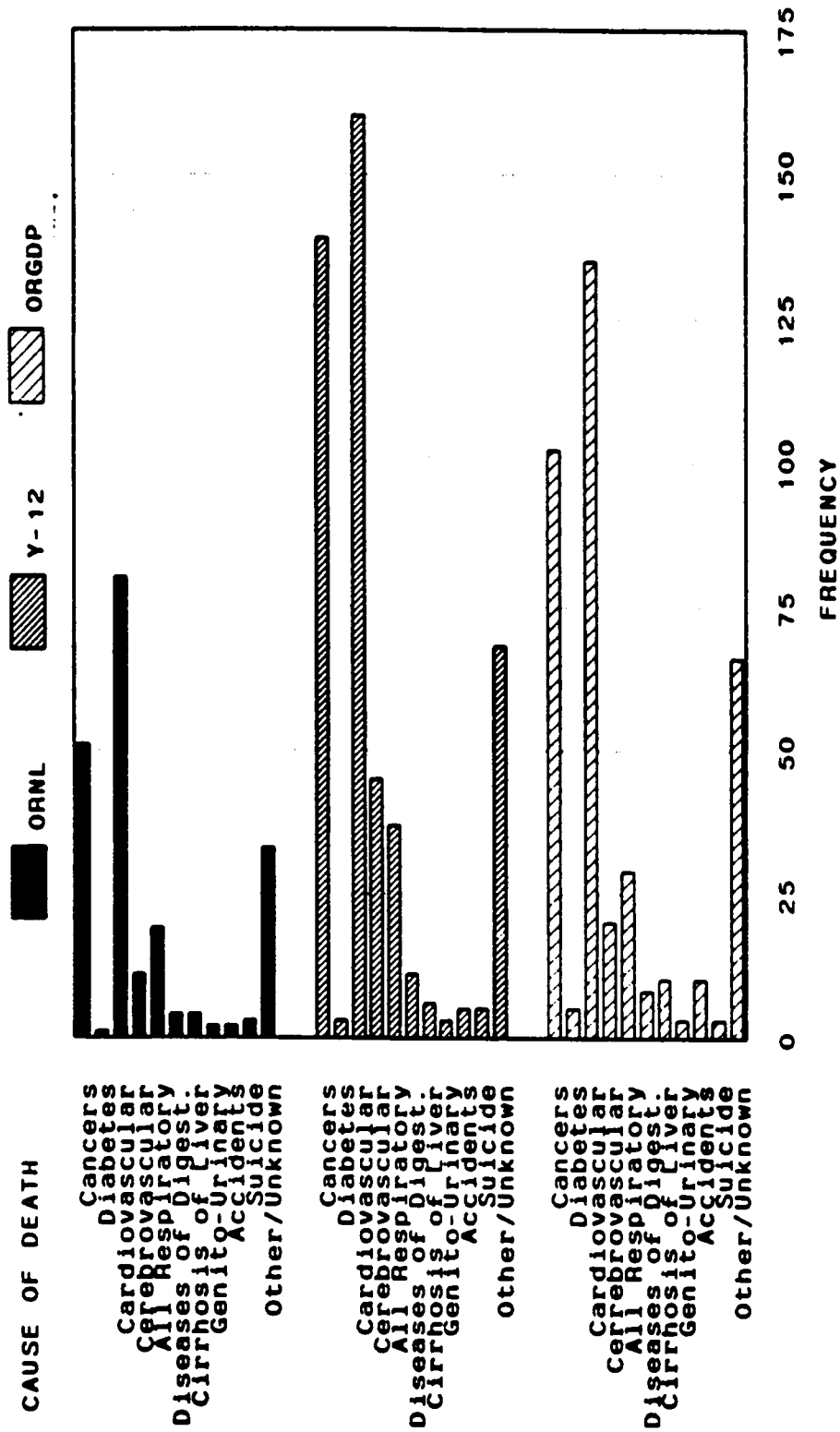
General Analyses of the Hourly Male Cohort by Facility

This phase of the male analyses involved the investigation of all and selected causes of death among hourly male retirees at ORNL, ORGDP, and Y-12. As hypothesized in Chapter I, it was expected that no differences would be found in the survivorship and mortality experience of male hourly retirees at the DOE-Oak Ridge facilities when compared separately with the U.S. population for all causes, all respiratory diseases, diabetes, diseases of the digestive system, cirrhosis of the liver, genito-urinary diseases, accidents, and suicide. Conversely, it was also hypothesized that all cancers and diseases of the circulatory system (i.e., cardiovascular and cerebrovascular diseases combined) in the hourly cohort would be elevated when compared to the general U.S. population.

The selected ten causes of hourly retiree death were confined to SMR analyses for all cancers (292 observed) and diseases of the circulatory system (532 observed) when examined by age of death. These causes of death comprised 76% of the all causes category (1,083 observed) in the cohort. The total frequency of deaths in the hourly population by facility is shown in Figure 7.

The male hourly retiree group contained 2,476 retirees (ORNL, 449; ORGDP, 813; and Y-12, 1,214), with 1,083 observed deaths. Death certificates were retrieved for 1,074 (99.2%) of these observed deaths, and 22 (2.0%) were lost to follow-up. Further analyses were performed on each facility to investigate age-specific SMRs for all and selected causes of death.

Source: ORAU, 1/31/90



Enumeration of Cause of Death: All Sites
for Hourly White Males: 1960-1984

Figure 7.

Table 13 presents the age-specific SMRs from all and selected causes of death and the number of person-years of observation for the hourly retiree data by 5-year age-groups at each facility. For the 50-59 age-group, the number of person-years and observed deaths was large enough to provide statistically interpretable data. However, at ORNL there were substantially fewer person-years in the 50-54 age-band and in the 85 and older age-band than in the other age-groups. In addition, each 5-year interval was distributed in a time-dependent manner such that a retiree in the 60-64 age-band contributed person-years to the two categories through which he passed until he was eligible to enter the 60-64 age-band. As a result, the hourly male group's sample size (24,423.4 person-years for the total male hourly cohort = 4,473.7 person-years for the ORNL population + 8,601.4 person-years for the ORGDP population + 11,348.3 person-years for the Y-12 population) and a 29-year average observation period was adequate for reliable data interpretations.

The cause-specific SMRs for hourly retirees by facility relative to the U.S. white male population for the years 1960 through 1984 are also shown in Table 13. Figure 7 provides an enumerated summary of selected causes of death by facility for the hourly group. The SMR of 1.09 (210 observed versus 192.8 expected) for all causes of death was as expected for ORNL hourly retirees. The SMR of 1.06 (482 observed versus 453.1 expected) for all causes was also as expected for the Y-12 male hourly retirees. However, the SMR of 1.17 (391 observed versus 333.9 expected; 95% C.I. = 1.06, 1.29) was significantly elevated for all causes in the ORGDP male hourly retiree group.

Mortality was significantly elevated for all cancers combined in both the ORGDP (102 observed versus 77.86 expected; SMR = 1.31; 95% C.I. = 1.06, 1.29) and Y-12 (139 observed versus 108.20 expected; SMR = 1.29; 95% C.I. = 1.08, 1.16) retired male hourly groups. The small confidence limits found relays the numerical stability of these estimates.

TABLE 13

Standardized Mortality Ratios (SMR) for All Causes of Death by Five-Year Age Groups for Hourly Males of ORNL, ORGDP, and the Y-12 Plant.

		ORNL			*All Causes (001-998)			ORGDP			Y-12		
		O / E ⁺	SMR	95% C.I. ⁺⁺	0	E		0	E		0	E ⁺	SMR 95% C.I. ⁺⁺
50-54	2	0.79	2.52	0.28-7.66	50-54	12	3.37	3.53	**1.84-6.20	50-54	10	2.61	3.85 **1.83-7.00
55-59	9	4.58	1.96	0.90-3.71	55-59	31	16.21	1.91	**1.30-2.71	55-59	53	14.83	3.58 **2.68-4.67
60-64	21	19.02	1.11	0.68-1.69	60-64	65	46.62	1.40	**1.08-1.78	60-64	91	53.72	1.69 **1.36-2.08
65-69	65	61.93	1.05	0.81-1.34	65-69	103	104.08	0.99	0.81-1.20	65-69	141	150.57	0.94 0.79-1.10
70-74	58	52.68	1.10	0.84-1.42	70-74	109	89.55	1.22	**1.00-1.47	70-74	103	123.18	0.83 0.68-1.01
75-79	35	32.89	1.06	0.74-1.50	75-79	49	50.35	0.97	0.72-1.29	75-79	52	71.74	0.73 **0.54-0.95
80-84	16	16.10	0.99	0.57-1.61	80-84	21	20.13	1.05	0.65-1.59	80-84	30	31.72	0.95 0.64-1.35
85+	4	4.84	0.83	0.22-2.04	85+	1	3.55	0.28	-	85+	3	4.76	0.63 0.13-1.73
Overall	210	192.82	1.09	0.95-1.25	391	333.86	1.17	**1.06-1.29		482	453.13	1.06	0.97-1.16

*ICD-8, International Classification of Diseases, Eighth Revision.

⁺Based on rates for U.S. white males, adjusted for age and calendar year.

⁺⁺Fisher's exact confidence limits.

**Statistically significant (P<0.05).

-Less than two deaths observed.

Continued on next page

TABLE 13 (continued)

Standardized Mortality Ratios (SMR) for Diseases of the Circulatory System by Five-Year Age Groups for Hourly Males of ORNL, ORGDP, and the Y-12 Plant.

*Circulatory Diseases (410-458)											
ORNL						ORGDP					
O / E*			SMR 95% C.I.**			O / E			SMR 95% C.I.**		

TABLE 13 (continued)

Standardized Mortality Ratios (SMR) for All Cancers by Five-Year Age Groups for Hourly Males of ORNL, ORGDP, and the Y-12 Plant.

*All Cancers (140-209)																				
ORNL										ORGDP									Y-12	
O / E*		SMR		95% C.I.**		0 / E		SMR		95% C.I.**		0 / E		SMR		95% C.I.**				
50-54	1	0.17	5.00	0.08-1.70	50-54	4	0.66	6.06	**1.62-14.90	50-54	4	0.57	7.06	**1.90-17.46						
55-59	6	1.12	5.46	**1.96-11.47	50-54	9	3.63	2.50	**1.13-4.67	55-59	22	3.65	6.03	**3.78-9.11						
60-64	5	4.88	1.02	0.33-2.34	60-64	20	11.46	1.74	**1.07-2.69	60-64	30	13.95	2.15	**1.45-3.07						
65-69	19	15.30	1.24	0.75-1.94	65-69	31	25.82	1.21	0.82-1.70	65-69	38	38.24	0.99	0.70-1.36						
70-74	13	12.46	1.04	0.56-1.78	70-74	22	21.36	1.03	0.65-1.56	70-74	25	29.89	0.83	0.54-1.23						
75-79	6	6.97	0.86	0.31-1.85	75-79	12	10.79	1.11	0.57-1.93	75-79	13	15.47	0.84	0.45-1.43						
80-84	0	2.91	-	-	80-84	4	3.67	1.08	0.29-2.69	80-84	6	5.81	1.03	0.38-2.22						
85+	1	0.63	1.59	-	85+	0	0.46	-	-	85+	1	0.62	1.66	-						
Overall	51	44.44	1.15	0.85-1.51		102	77.86	1.31	**1.06-1.29		139	108.20	1.29	**1.08-1.16						

*ICD-8, International Classification of Diseases, Eighth Revision.

*Based on rates for U.S. white males, adjusted for age and calendar year.

**Fisher's exact confidence limits.

**Statistically significant ($P < 0.05$).

-Less than two deaths observed.

Continued on next page

TABLE 13 (continued)

Person Years by Five-Year Age Groups for Hourly Retirees of ORNL, ORGDP, and the Y-12 Plant.

Age	ORNL	ORGDP	Y-12	Total Person Years
50-54	78.9	304.4	252.0	635.3
55-59	289.9	955.9	944.0	2189.8
60-64	796.7	1885.6	2268.5	4950.8
65-69	1712.9	2888.0	4251.6	8852.5
70-74	1000.4	1710.9	2381.8	5093.1
75-79	425.2	657.1	939.9	2022.2
80-84	143.6	180.3	284.8	608.7
85+	26.1	19.2	25.7	71.0
TOTALS	4473.7	8601.4	11348.3	24423.4

Diseases of the circulatory system were the prime contributors to the overall mortality rates for blue collar retirees at both ORNL (SMR = 1.02; 95% C.I. = 0.83, 1.23) and Y-12 (SMR = 0.96; 95% C.I. = 0.84, 1.09). It should be noted, however, that when examined separately from other circulatory diseases, cerebrovascular diseases were significantly elevated in the Y-12 group (45 observed versus 32.4 expected; 95% C.I. = 1.01, 1.86). Diseases of the circulatory system (SMR = 1.04; 95% C.I. = 0.80, 1.20) were not a major contributor in elevating the overall mortality rates of the ORGDP group.

The most noteworthy findings from the SMR analyses of the hourly groups were the consistent associations in the results of the all cancers category in the ORGDP and the Y-12 populations. These patterns were clearly conveyed when age-specific SMRs were analyzed within 5-year age-bands for ORGDP and Y-12 (see Table 13).

Age-Specific SMR Analyses of the Male Hourly Cohort by Facility

Table 13 displays the three principal contributors to mortality for hourly males by 5-year intervals in age categories 50 to 85, and older. For all causes at ORNL, the age-specific SMRs were as expected for all age-bands. Even though the age-band 50-54 had an SMR of 2.52 (95% C.I. = 0.28, 7.66), which was not significant, it represented only two observed deaths versus 0.79 expected deaths. As a result, no statistically significant instances of elevated deaths for all causes were noted in the ORNL blue collar group.

The number of deaths due to all causes combined in the ORGDP blue collar group for age-bands 50-54 (SMR = 3.37; 95% C.I. = 1.84, 6.20), 55-59 (SMR = 1.91; 95% C.I. = 1.30, 2.71), 60-64 (SMR = 1.40; 95% C.I. = 1.08, 1.78), and 70-74 (SMR = 1.22; 95% = 1.00, 1.47) was significantly elevated when compared to the U.S. population. The significantly elevated mortality trend began to abate at age-bands 65-69 (SMR = 0.99; 95% C.I. = 0.81, 1.20), 75-79 (SMR = 0.97; 95% C.I. = 0.72, 1.29), 80-84 (SMR = 1.05; 95% C.I. = 0.65,

1.59), and 85 and older (SMR = 0.28; 1.00 deaths observed versus 3.55 expected). The number of observed deaths in these particular age-bands was commensurate with the U.S. population.

The Y-12 group was similar to the ORGDP group in terms of the increased number of deaths due to all causes. For example, in the Y-12 blue collar group, the age-bands 50-54 (SMR = 3.85; 95% C.I. = 1.83, 7.00), 55-59 (SMR = 3.58; 95% C.I. = 2.68, 4.67) and 60-64 (SMR = 1.69; 95% C.I. = 1.36, 2.08) were all significantly elevated. As in the ORGDP group, the significantly elevated mortality trend began to decline at the 65-69 age-band (SMR = 0.94; 95% C.I. = 0.79, 1.10) and, therefore, began to approach the U.S. population norm. The similarity in number of deaths due to all causes between Y-12 and ORGDP ended at age-band 65-69. In fact, the Y-12 group experienced a mortality deficit for the remaining age-bands of 70-74 (SMR = 0.83; 95% C.I. = 0.68, 1.01), 75-79 (SMR = 0.73; 95% C.I. = 0.54, 0.95), 80-84 (SMR = 0.95; 95% C.I. = 0.64, 1.35), and 85 and older (SMR = 0.63; 95% C.I. = 0.13, 1.73), with the deficit in the 75-79 age-band being statistically significant.

The deficit mortality for the Y-12 group age-bands was consistent with the HWE. However, it was surprising to find that the age-band 75-79 had a statistically significant mortality deficit. Because of the possible accumulative effects of latency from multivariied sources such as smoking and chemical exposure, the mortality experience was expected to be similar to that of the U.S. population for this age-band.

In general, the overall death rates from all causes across the facilities were higher than expected. Relative mortality elevations for ORNL in hourly males aged 50-79 contributed to the overall increase in the SMR value (1.09). However, none of the age-bands in the ORNL hourly male group contained significantly elevated death rates. Conversely, both ORGDP and Y-12 exhibited statistically significant mortality increases due to all causes

combined in the blue collar population for the ages 50-64 (see Table 13).

The statistically significant increases for ages 50-64 and 70-74 proved to be the major contributors to the overall significantly elevated SMR (1.17) in the ORGDP blue collar population. However, the significantly elevated death rates in the Y-12 male blue collar cohort for the ages 50-64 were stabilized by a significant deficit for all causes (age 75-79, SMR = 0.73; 95% C.I. = 0.54-0.95) in this population, resulting in a non-statistically significant increase in the overall death rate (SMR = 1.06; 95% C.I. = 0.97, 1.16). In this study, SMR values for the blue collar male retirees across each DOE-Oak Ridge facility were determined by using the U.S. population as the standard for comparison. The findings from the analyses of these facilities suggest that there was no carry-over in the HWE for the blue collar cohort.

For all cancers at ORNL, the age-specific SMR was elevated for the age-band 50-54 (SMR = 5.00; 95% C.I. = 0.08, 1.70). This elevation was based on 1.00 death observed and 0.17 expected. Likewise, for the age-band 55-59 (SMR = 5.46; 95% C.I. = 1.96, 11.47) the number of deaths was statistically significant. One should use caution when interpreting this significantly elevated SMR (5.46) for the all cancers category in this age-band because it was based only on 6.00 observed, versus 1.12 expected, cancer deaths. Such small numbers are numerically unstable because of the wide confidence interval involved. All other age-bands in the ORNL blue collar group demonstrated mortality rates similar to that of the general population.

ORGDP age-specific SMRs for all cancers were significantly elevated for the age-bands 50-54 (SMR = 6.06; 95% C.I. = 1.62, 14.90), 55-59 (SMR = 2.50; 95% C.I. = 1.13, 4.67), and 60-64 (SMR = 1.74; 95% C.I. = 1.07, 2.69). The findings for age-bands 50-54 and 55-59 were based on four and nine deaths observed versus 0.66 and 3.63 expected deaths,

respectively. There were no statistically significant elevations or decrements for all cancers in the ORGDP group for the remaining age-bands 65-69, 70-74, 75-79, 80-84, and 85 and older.

The all cancers category in the Y-12 blue collar group was similar to the ORGDP hourly cohort because there were significantly elevated mortality patterns for ages 50 through 64. For example, SMRs for all cancers were significantly elevated for age-bands 50-54 (SMR = 7.06; 95% C.I. = 1.90, 17.46), 55-59 (SMR = 6.03; 95% C.I. = 3.78, 9.11), and 60-64 (SMR = 2.15; 95% C.I. = 1.45, 3.07). These findings were based on four observed deaths (0.57 expected), 22 observed deaths (3.65 expected), and 30 observed deaths (13.95 expected), respectively. The significant excess in mortality declined and began to appear similar to that of the U.S. population in the age-band 65-69 (SMR = 0.99; 95% C.I. = 0.70, 1.36). No statistically significant deviations from the expected values were observed in the remaining age-bands 70-74 (SMR = 0.83; 95% C.I. = 0.54, 1.23), 75-79 (SMR = 0.84; 95% C.I. = 0.45, 1.43), 80-84 (SMR = 1.03; 95% C.I. = 0.38, 2.22), and 85 and older (SMR = 1.66; 1.00 observed death versus 0.67 expected).

Table 13 contains information about the 292 cancer deaths which occurred among hourly retirees of all facilities combined. The deaths are shown by 5-year age-bands to demonstrate which hourly retirees in this study were at a potentially elevated risk of age-specific mortality from cancer deaths. Statistically significant deviations from the overall expected values were observed for all cancers in the ORGDP (SMR = 1.31; 95% C.I. = 1.06, 1.29) and Y-12 (SMR = 1.29; 95% C.I. = 1.08, 1.16) blue collar male populations. The number of cancer deaths in the ORNL blue collar male population was within the expected range. Mortality from all cancers was primarily responsible for the higher-than-expected SMRs in the all causes category across the three plant sites.

The mortality results for diseases of the circulatory system in the ORNL blue collar group show the SMRs to be as expected for all age-bands; i.e., 50-54 (SMR = 2.56; 1.00 observed death versus 0.39 expected), 55-59 (SMR = 0.44; 1.00 observed death versus 2.31 expected), 60-64 (SMR = 1.22; 95% C.I. = 0.36, 2.12), 65-69 (SMR = 0.99; 95% C.I. = 0.68, 1.39), 70-74 (SMR = 1.03; 95% C.I. = 0.70, 1.47), 75-79 (SMR = 1.12; 95% C.I. = 0.69, 1.71), 80-84 (SMR = 0.95; 95% C.I. = 0.43, 1.79), and 85 and older (SMR = 0.33; 1.00 observed death versus 3.00 expected). The ORGDP blue collar group also contained SMRs as expected for all age-bands for diseases of the circulatory system; i.e., 50-54 (SMR = 2.94; 95% C.I. = 0.94, 6.63), 55-59 (SMR = 1.65; 95% C.I. = 0.90, 2.76), 60-64 (SMR = 0.94; 95% C.I. = 0.59, 1.40), 65-69 (SMR = 0.89; 95% C.I. = 0.66, 1.18), 70-74 (SMR = 1.18; 95% C.I. = 0.90, 1.53), 75-79 (SMR = 1.02; 95% C.I. = 0.68, 1.46), 80-84 (SMR = 0.85; 95% C.I. = 0.41, 1.55), and 85 and older (0.00 observations versus 0.08 expected). In general, there were no strong upward or downward mortality trends apparent in either of the ORNL or the ORGDP blue collar groups.

At Y-12, however, significantly elevated SMRs for diseases of the circulatory system were seen for age-bands 50-54 (SMR = 3.90; 95% C.I. = 1.26, 8.90), 55-59 (SMR = 2.01; 95% C.I. = 1.12, 3.30), and 60-64 (SMR = 1.45; 95% C.I. = 1.03, 1.97). These findings were based on 5.00 observed deaths (1.28 expected), 15.00 observed deaths (7.48 expected), and 40.00 observed deaths (27.62 expected), respectively. Mortality from circulatory diseases were below expected numbers for the remaining age-bands of 65-69 (SMR = 0.90; 95% C.I. = 0.70, 1.13), 70-74 (SMR = 0.76; 95% C.I. = 0.57, 1.00), 75-79 (SMR = 0.82; 95% C.I. = 0.56, 1.15), 80-84 (SMR = 0.92; 95% C.I. = 0.53, 1.47), and 85 and older (SMR = 0.68; 95% C.I. = 0.08, 2.06). A statistically significant deficit of deaths was not found in the analysis of circulatory diseases for the Y-12 blue collar group.

In the analyses based on data of all hourly retirees, SMRs for circulatory diseases were highest in the 50-54 age-band (see Table 13). Although there were some obvious fluctuations of circulatory disease SMRs by age, the overall SMRs by plant were as expected.

**Generalizations Regarding the Mortality Experience
of the Hourly Male Cohorts at the Three Separate
Sites and Hypotheses Outcomes**

Mortality among the hourly groups at each of the three plants was compared separately with that of the U.S. population. The following generalizations were made regarding the analyses of mortality experiences among each group for all causes and two broad selected causes of death:

ORNL

1. The ORNL hourly male group's mortality experience for all causes combined and circulatory diseases was similar to that of the U.S. population.
2. The ORNL hourly male group experienced statistically significant mortality from all cancers in the age-band 55-59 (95% C.I. = 1.96, 11.47). The wide confidence interval and the small number of deaths (6.00 observed versus 1.12 expected) from this cause made any specific interpretation of the finding difficult. Nonetheless, this increase was investigated and will be discussed in more detail later in this chapter.
3. There was no apparently HWE in the ORNL blue collar group as demonstrated by the fact that the overall death rate for all causes was in excess of the expected value.

ORGDP

1. When compared to a similar segment of the U.S. population, the hourly male cohort from ORGDP exhibited statistically significant elevated mortality

from all causes combined between the ages 50-64 and 70-74. The significantly elevated SMRs were also present in this cohort for all cancers between the ages 50-64.

2. The significantly elevated mortality patterns in the ORGDP hourly cohort for all causes combined and all cancers combined were strikingly similar to those of the Y-12 hourly cohort for ages 50-64.
3. The SMRs for all causes combined and all cancers combined were never less than unity.
4. The total number of deaths from all causes combined and all cancers combined in the ORGDP group was significantly elevated when compared to a similar segment of the general population.
5. Since no strong deficit mortality trend was found in the ORGDP hourly group, one may suspect that the HWE was nullified by the long follow-up period (≥ 29 years).

Y-12

1. When compared to the U.S. population, the hourly male cohort from Y-12 displayed statistically significant elevated mortality from all causes combined between the ages 50-64. The significantly elevated trend was also present in this cohort for all cancers combined and all circulatory diseases combined between the ages 50-64.
2. The significantly elevated mortality patterns in the Y-12 hourly cohort for all causes and all cancers were remarkably similar to those of the ORGDP hourly cohort for ages 50-64.

3. A strong deficit mortality trend was apparent in the Y-12 hourly cohort for all causes and circulatory diseases combined between the ages 65-85, and older. SMRs for ages 65-85 and older were consistently less than unity for all causes combined and circulatory diseases. These findings tend to indicate the presence of a HWE.
4. When compared to the U.S. population, the Y-12 hourly population showed significantly lower mortality (52 observed versus 71.74 expected) for all causes combined between the ages 75-79.
5. When compared to the U.S. population, the Y-12 hourly population exhibited a statistically significant excess in mortality for the all cancers category.

The mortality outcomes for the hourly male cohort reject null hypothesis-2 (there will be no differences in survivorship and mortality experience for blue collar retirees of ORNL, ORGDP, or Y-12 when compared separately to the U.S. for all causes, diabetes, all respiratory diseases, diseases of the digestive system, cirrhosis of the liver, genito-urinary diseases, accidents, and suicide). The MAS used in this study showed SMRs at each facility to be essentially as expected for cause-specific mortality and for all causes combined at ORNL and Y-12. There was a strong upward trend in death rates at each facility for those individuals who retired before age 65. These findings indicate an absence of carry-over in the HWE among early retirees (i.e., those who retired before age 65).

The acceptance of alternative hypothesis-2 (excess in death rates will be seen in the blue collar retirees when compared separately to the U.S. for all cancers and circulatory diseases [i.e., cardiovascular and cerebrovascular diseases combined]) further strengthen the postulation that death rates are impacted by socioeconomic status. These findings also present strong evidence that early retirees (i.e., before age 62) are at a significantly elevated

risk of dying from all cancers. Possible explanations for the unexpected significantly high death rate from all cancers and other slightly elevated specific causes are discussed later in this chapter.

General Analyses of the Pooled Salaried Male Cohort

The third phase of the male analyses involved the investigation of mortality outcome for all and selected causes of death among a single combined salaried male cohort from ORNL, ORGDP, and Y-12 (see Table 14 for selected causes). As hypothesized in Chapter I, it was expected that no differences would be found in the survivorship and mortality experience of pooled salaried males retirees at the DOE-Oak Ridge facilities when compared collectively with the U.S. population for all causes, all cancers, all respiratory diseases, diabetes, cirrhosis of the liver, accidents, suicide, and genito-urinary diseases. However, it was hypothesized that differences in survivorship and mortality would be seen as slightly elevated SMRs in the pooled salaried male cohort when compared to the U.S. population for circulatory diseases (i.e., cerebrovascular and cardiovascular diseases combined). Table 14 lists by ICD8 category all causes and the ten selected causes that were investigated.

The ten select causes of death for the pooled salaried male retirees were confined to analyses of SMRs for all cancers combined (124 observed) and all circulatory diseases combined (267 observed) since they comprised 73% of deaths from all causes combined (537 observed) in the cohort. Table 15 gives the age-specific SMRs for all and selected causes and the number of person-years of observation for the pooled salaried retired group by 5-year age-bands. For the interval between 50-84, the number of person-years and the number of observed deaths was large enough to provide reliable data. The age-band 85 and older had substantially fewer person-years than the succeeding age-bands. Person-years for each 5-year

TABLE 14

Specific Causes of Death Under Investigation According to ICD8 Code

Cause of Death	ICD8 Code Numbers
All Causes	001-998
Cancers	140-209
Diabetes	250
Cardiovascular Diseases	390-413
Cerebrovascular Diseases	430-438
Respiratory Diseases	460-519
Digestive System Diseases	520-577
Cirrhosis of the Liver	571
Genito-Urinary Diseases	580-629
Accidents	800-949
Suicides	950-959

TABLE 15

Standardized Mortality Ratios (SMR) for All and Selected Causes of Death by Five-Year Age Bands for Combined Salaried Population

		*All Causes		All Cancers		Circulatory Diseases			
		O / E*	SMR 95% C.I.**	O / E	SMR 95% C.I.**	0	E	SMR	95% C.I.**
50-54	9	4.89	1.84 0.84,3.49	50-54 3	1.06 2.84 -	50-54	1	2.41	0.01,2.31
55-59	31	26.25	1.18 0.80,1.68	55-59 8	6.50 1.23 0.53,2.43	55-59	17	13.21	0.75,2.06
60-64	110	77.28	1.42 **1.17,1.72	60-64 23	20.27 1.14 0.72,1.70	60-64	49	39.57	1.24 0.92,1.64
65-69	162	189.40	0.86 **0.73,0.99	65-69 41	48.55 0.85 0.61,1.15	65-69	84	100.21	0.84 0.67,1.04
70-74	124	152.17	0.81 **0.68,0.97	70-74 30	37.20 0.81 0.54,1.15	70-74	65	82.34	0.79 0.61,1.01
75-79	68	74.83	0.91 0.71,1.15	75-79 13	16.22 0.80 0.43,1.37	75-79	35	41.96	0.83 0.58,1.16
80-84	26	26.13	0.99 0.65,1.46	80-84 5	4.76 1.05 0.34,2.45	80-84	11	15.31	0.72 0.36,1.29
85+	7	5.24	1.34 0.54,2.75	85+ 1	0.68 1.48 -	85+	5	3.28	1.53 0.49,3.56
Overall	537	556.19	0.97 0.89,1.05	124	135.23 0.92 0.79,1.01	267	298.28	0.90	0.79-1.01

*ICD-8, International Classification of Diseases, Eighth Revision.

*Based on rates for U.S. white males, adjusted for age and calendar year.

**Fisher's exact confidence limits.

**Statistically significant ($P < 0.05$).

-Less than two deaths observed.

age-band were distributed in a time-dependent manner such as was performed in the previous phases of these analyses. Hence, by using this method 15,048.3 total person-years were accrued by pooling the salaried population.

Table 15 also shows the cause-specific SMRs for pooled salaried retirees relative to the U.S. white male population for the years 1960 through 1984. The overall SMR for all causes in the pooled salaried group was lower than expected (537 observed versus 556.19 expected; 95% C.I. = 0.89, 1.05). A lower than expected number of deaths was also seen in the all cancers combined (124 observed versus 135.23 expected; 95% C.I. = 0.76, 1.09) and circulatory diseases (267 observed versus 298.28 expected; 95% C.I. = 0.79, 1.01) categories. Although there were significant deficits of mortality due to all causes combined among the retired salaried workers in the 65-69 and 70-74 age-bands and there was a statistically significant increase in the 60-64 age-band, the lower-than-expected mortality was not significant in any of these categories.

Age-Specific SMR Analyses of the Pooled Salaried Male Cohort

The pooled salaried male population contained 1,581 retirees, of which 537 were observed to be dead. Death certificates were retrieved for 534 (99.4%) of these observed deaths, and 12 (0.8%) were lost to follow-up. An analysis was performed on the pooled salaried population to investigate age-specific SMRs for all and selected causes.

Table 15 displays the three principal contributors to mortality in the pooled salaried male data by 5-year age-bands for ages 50-85, and older. For all causes in the pooled white collar population, the age-specific SMRs were slightly elevated for the age-bands 50-54 (SMR = 1.84; 95% C.I. = 0.84, 3.49) and 55-59 (SMR = 1.18; 95% C.I. = 0.80, 1.68). The number of deaths due to all causes in the pooled white collar population for the age-band 60-64 (SMR = 1.42; 95% C.I. = 1.17, 1.72) was significantly elevated. The Y-12 salaried male

cohort proved to be a major contributor to the significant excess in mortality for the pooled white collar group in the age-band 60-64.

When all three facilities were examined collectively as a pooled salaried group, there was a statistically significant deficit in the number of deaths for the age-bands 65-69 (SMR = 0.86; 95% C.I. = 0.73, 0.99) and 70-74 (SMR = 0.81; 95% C.I. = 0.68, 0.97). This finding is noteworthy because when the facilities were investigated singularly no significant deficit in SMRs was present in any salaried group for the age-bands 65-69 and 70-74. Hence, this finding supports the idea that, within the post retirement age-band 65-74, the healthy worker selection process still operated. The remaining age-bands 75-79 (SMR = 0.91; 95% C.I. = 0.71, 1.15), 80-84 (SMR = 0.99; 95% C.I. = 0.65, 1.46), and 85 and older (SMR = 1.34; 95% C.I. = 0.54, 2.75) for all causes basically demonstrated a steady decline in the HWE, and the mortality characteristics of these age-bands increasingly began to resemble those of the general population.

For all cancers within the pooled salaried male cohort, the age-specific SMR was elevated for the age-band 50-54 (SMR = 2.84). However, the excess was based on 3.00 observed deaths and 1.06 expected deaths, making any meaningful interpretation of the finding difficult. The SMRs for the age-bands 55-59 (SMR = 1.23; 95% C.I. = 0.53, 2.43) and 60-64 (SMR = 1.14; 95% C.I. = 0.72, 1.70) were as expected. The succeeding age-bands 65-69 (SMR = 0.85; 95% C.I. = 0.61, 1.15), 70-74 (SMR = 0.81; 95% C.I. = 0.54, 1.15), and 75-79 (SMR = 0.80; 95% C.I. = 0.43, 1.37) for all cancers exhibited lower-than-expected mortality when compared to a similar segment of the U.S. population.

The mortality deficit for these age-bands was mainly attributed to the lower-than-expected number of deaths for ages 65-79 at ORNL and ORGDP. This deficit finding provides further evidence of the carry-over of the HWE in post-retirement years. The

mortality rates of the remaining age-bands 80-84 (SMR = 1.05; 5.00 observed deaths versus 4.76 expected) and 85 and older (SMR = 1.48; 1.00 observed death versus 0.68 expected) demonstrated that, as the cohort aged, it increasingly came to resemble the general population in its health status characteristics.

The mortality results for diseases of the circulatory system in the pooled salaried males were fairly consistent with the previous findings for this cohort. The SMR for the age-band 50-54 (SMR = 1.09; 95% C.I. = 0.01, 2.31) in the circulatory diseases category exhibited a deficit. The deficit, however, was based on 1.00 observed death and 2.41 expected. Therefore, such small numbers made any meaningful interpretation difficult. SMRs were as expected for the age-bands 55-59 (SMR = 1.09; 95% C.I. = 0.75, 2.06) and 60-64 (SMR = 1.24; 95% C.I. = 0.92, 1.64). The succeeding age-bands 65-69 (SMR = 0.84; 95% C.I. = 0.67, 1.04), 70-74 (SMR = 0.79; 95% C.I. = 0.61, 1.01), 75-79 (SMR = 0.83; 95% C.I. = 0.52, 1.16), and 80-84 (SMR = 0.72; 95% C.I. = 0.36, 1.29) for circulatory diseases displayed a lower-than-expected number of deaths. Similar deficits were seen across these age-bands when each site was investigated singularly. More importantly, these findings show that the HWE actively operated in the pooled salaried cohort for ages 65-84.

Generalizations Regarding the Mortality Experience of the Pooled Salaried Male Cohort and Hypotheses Outcomes

The mortality experience among the pooled salaried male cohort was compared to a similar segment of the U.S. population. Analyses of this comparison were performed for all and two broad selected causes of death by 5-year age intervals. The resulting generalizations were made regarding these analyses:

1. There was a consistent deficit pattern in mortality for all causes, all cancers, and circulatory disease in the pooled salaried male cohort between the ages 65-74.

2. The pooled salaried group exhibited lower than expected overall mortality for all causes, all cancers, and circulatory diseases when compared to a similar segment of the U.S. population.
3. The statistically significant mortality rate for all causes in the pooled salaried male cohort for the age-band 60-64 was principally attributed to a significant excess for all causes in a similar group at Y-12.
4. Statistically significant deficits for all causes in the pooled salaried male cohort for ages 65-74 provided strong evidence that an active carry-over in the HWE was present during those post-retirement years.

These findings support null hypothesis-3 (there will be no differences in survivorship and mortality experience for the combined salaried male population from ORNL, ORGDP, and Y-12 when compared to the U.S. for all causes, all cancers, diabetes, all respiratory diseases, diseases of the digestive system, cirrhosis of the liver, genitor-urinary diseases, accidents, and suicide). Overall deficit SMRs in the diseases investigated provided strong support that the death rate for salaried male retirees is generally lower than the U.S. population. It is postulated by this researcher that the low death rates in the white collar male population can primarily be attributed to carry-over in the HWE.

Alternative hypothesis-3 was rejected (excess in the death rates will be seen for the combined salaried male population at ORNL, ORGDP, and Y-12 when compared to the U.S. for all circulatory diseases [i.e., cardiovascular and cerebrovascular diseases combined]). The lower-than-expected death rates in the combined salaried male population provides additional evidence that the HWE actively continues in post retirement.

General Analyses of the Pooled Hourly Cohort

The fourth phase of the male analyses involved the investigation of mortality outcome for all and selected causes of death among a single combined hourly male cohort from ORNL, ORGDP, and Y-12. As hypothesized in Chapter I, it was expected that no differences would be found in the survivorship and mortality experience of pooled hourly male retirees at these government facilities when they were compared collectively with the U.S. population for diabetes, all respiratory diseases, cirrhosis of the liver, accidents, suicide, and genitourinary diseases. However, it was expected that differences in survivorship and mortality would be seen as elevated SMRs in the pooled hourly cohort when compared to the U.S. population for all causes, all cancers, and circulatory diseases (i.e., cerebrovascular and cardiovascular diseases combined). Table 14 shows by ICD8 category all causes and the ten selected causes that have been investigated.

The investigation of the ten selected causes of death for the pooled hourly male retirees was confined to analyses of SMRs for all cancers (292 observed) and circulatory diseases (532 observed) since they comprised 76% of the deaths from all causes (1,083 observed) in the cohort. The age-specific SMRs for all and selected causes and the number of person-years of observation are shown in Table 16 for the pooled hourly retired group by 5-year age-bands. For the intervals between ages 50-84, the number of person-years and the number of observed deaths were large enough to provide reliable data. The age-band 85 and older had substantially fewer person-years than the succeeding age-bands. Person-years for each 5-year age-band were distributed in a time-dependent manner such as performed in the previous phases of these analyses. Thus, by using this method 24,420.3 total person-years were accrued by pooling the hourly population.

TABLE 16

Standardized Mortality Ratios (SMR) for All and Selected Causes of Death by Five-Year Age Bands for Combined Hourly Population

All Causes					All Cancers					Circulatory Diseases				
O / E*		SMR	95% C.I.**		O / E		SMR	95% C.I.**		O / E		SMR	95% C.I.**	
50-54	24	6.78	3.54	**2.27,5.27	50-54	9	1.40	6.43	- , -	50-54	11	3.39	3.24	**1.62,5.80
55-59	93	35.62	2.61	**2.10,3.20	50-54	37	8.41	4.40	**3.10,6.07	55-59	30	18.28	1.64	**1.11,2.34
60-64	177	119.36	1.48	**1.27,1.72	60-64	55	30.29	1.82	**1.36,2.36	60-64	75	62.05	1.21	0.95,1.52
65-69	309	316.58	0.98	0.87,1.09	65-69	88	79.35	1.11	0.89,1.37	65-69	155	169.41	0.92	0.78,1.07
70-74	269	265.41	1.01	0.89,1.14	70-74	60	63.71	0.94	0.72,1.21	70-74	139	145.15	0.96	0.81,1.13
75-79	136	154.97	0.88	0.74,1.04	75-79	31	33.24	0.93	0.63,1.32	75-79	83	87.54	0.95	0.76,1.18
80-84	67	67.95	0.99	0.76,1.25	80-84	10	12.39	0.81	0.39,1.48	80-84	86	39.80	0.91	0.63,1.25
85+	8	13.15	0.61	0.26,1.20	85+	2	1.71	1.17	- , -	85+	3	8.16	0.37	0.07,1.08
Overall	1083	979.81	1.11	**1.04,1.17		292	230.50	1.27	**1.13,1.42		532	533.78	1.00	0.91,1.09

*ICD-8, International Classification of Diseases, Eighth Revision.

*Based on rates for U.S. white males, adjusted for age and calendar year.

**Fisher's exact confidence limits.

**Statistically significant ($P < 0.05$).

-Less than two deaths expected.

Table 16 also shows the cause-specific SMRs for pooled hourly retirees relative to the U.S. white male population for the years 1960 through 1984. The overall SMR for all causes in the pooled hourly groups was significantly elevated (1,083.00 observed versus 979.81 expected; 95% C.I. = 1.04, 1.17). The overall SMR for the all cancers category was also significantly elevated (292.00 observed versus 230.50 expected; 95% C.I. = 1.13, 1.42); whereas the circulatory diseases category (532.00 observed versus 533.79 expected; 95% C.I. = 0.91, 1.09) exhibited an SMR (1.00) that was more in line with that of the general population. It should be noted that, in the pooled hourly cohort, the overall SMRs for all and selected causes of death were never less than unity.

Age-Specific SMR Analysis of the Pooled Hourly Male Cohort

The pooled hourly male population contained 2,476 retirees with 1,083 observed deaths. Death certificates were retrieved for 1,074 (99.2%) of these observed deaths, and 22 (0.9%) were lost to follow-up. An analysis was performed on the pooled hourly population to investigate age-specific SMRs for all and selected causes.

Table 16 displays the three principal contributors to mortality in the pooled hourly male data by 5-year age-bands for ages 50-85, and older. For all causes in the pooled blue collar population, the age-specific SMRs were significantly elevated in age-bands 50-54 (SMR = 3.54; 95% C.I. = 2.27, 5.27), 55-59 (SMR = 2.61; 95% C.I. = 2.11, 3.20), and 60-64 (SMR = 1.48; 95% C.I. = 1.27, 1.72). The mortality pattern in these age-bands was generally similar to the mortality patterns exhibited in the individual analyses of the ORGDP and Y-12 blue collar populations. The remaining age-bands (65-85 and older) for all causes combined had SMRs which ranged from 0.61 to 1.01; however, there were no statistically significant elevations or decrements for the remaining age-bands within the pooled hourly group for the all causes category.

In the all cancers combined category the age-band 50-54 exhibited an elevated SMR (6.43). The elevation in this particular age-band was based on 9.00 observed deaths versus 1.40 expected. The two succeeding age-bands 55-59 (SMR = 4.40; 95% C.I. = 3.10, 6.07) and 60-64 (SMR = 1.82; 95% C.I. = 1.37, 2.36) were both significantly elevated. The significant excess in mortality within the pooled blue collar group was principally attributed to the high number of deaths within the ORGDP and Y-12 populations for ages 55-64. The remaining age-bands (65-85 and older) for all cancers had SMRs which ranged from 0.81 to 1.17. Here again, no statistically significant elevations or decrements were seen in the remaining age-bands for the all cancers category.

Analyses in which SMRs were computed by 5-year age-bands were also performed for circulatory diseases. In the age-bands 50-54 (SMR = 3.24; 95% C.I. = 1.62, 5.80) and 55-59 (SMR = 1.64; 95% C.I. = 1.11, 2.34) mortality from circulatory diseases was significantly elevated. Mortality was as expected for the succeeding age-bands between 60-84. The low SMR (0.37) in the 85 and older age-band was based on 3.00 observed deaths versus 8.16 expected deaths. No significant deficits for circulatory diseases were shown in this analysis of the pooled blue collar population.

Generalizations Regarding the Mortality Experience of the Pooled Hourly Male Cohort and Hypotheses Outcomes

The mortality experience within the pooled hourly male cohort was compared to a similar segment of the U.S. population. Analyses of that comparison were performed for all and two broad select causes of death by 5-year age intervals. The resulting generalizations were made regarding these analyses:

1. There was a regular pattern of significantly increased mortality for all causes, all cancers, and circulatory diseases within the age-bands 50-64 for pooled blue

collar retirees. The statistically significant increase in mortality within the aforementioned age-bands was principally attributed to similar significantly elevated deaths as those seen in individual analyses of the ORGDP and Y-12 hourly populations.

2. Overall SMRs for causes of death under investigation were never less than unity. In fact, the overall SMRs for the pooled blue collar population was significantly increased for all causes and all cancers.
3. There was no apparent HWE in the pooled blue collar population.

Null hypothesis-4 (there will be no differences in survivorship and morality experience for the combined hourly male populations of ORNL, ORGDP, and Y-12 when compared to the U.S. for diabetes, all respiratory diseases, cirrhosis of the liver, genito-urinary diseases, accidents, and suicide) was accepted. No strong upward or downward trend in mortality was evident. The number of deaths observed from these causes was generally as expected.

However, the acceptance of alternative hypothesis-4 (excess in death rates will be seen for the combined hourly populations of ORNL, ORGDP, and Y-12 when compared to the U.S. for all causes, all cancers, circulatory diseases [i.e., cardiovascular and cerebrovascular diseases combined], and diseases of the digestive system) provides further support to the notion that one's longevity is strongly associated with one's socioeconomic status. These data also show that early blue collar male retirees (i.e., before age 65) are at a more elevated mortality risk than those who terminate employment after age 65.

Analyses of the Direct Comparison of the Standardized Male Pooled White Collar Population to the Male Pooled Blue Collar Population

The fifth and final phase of the male retiree analyses involved the investigation of mortality outcome for all and selected causes of death within a single combined blue collar

cohort from ORNL, ORGDP, and Y-12. The major difference in this analysis from previous analyses was that the pooled white collar retirees from the same facilities were used as the standard for the comparison. It was hypothesized in Chapter I that such a comparison would produce elevated SMRs in the blue collar population. It was further hypothesized that mortality gradients would be more elevated in the age-bands 50-74. This analysis was limited to the investigation of all causes, all cancers, and diseases of the circulatory system since they comprised the vast majority of deaths in both the white and blue collar populations. The following age-band formula was used to convert the white collar cohort into a standardized population:

$$\begin{aligned}
 \text{Standardized Group} &= \frac{\text{Observed White Collar}}{\text{Person-Years White Collar}} \times \text{Person-Years Blue Collar} \\
 &= \text{Expected Blue Collar (based on white collar)} \\
 &= \frac{\text{Observed Blue Collar}}{\text{Expected Blue Collar}} \text{ (based on standardized blue collar)}
 \end{aligned}$$

Table 17 shows the cause-specific SMRs for pooled blue collar male retirees relative to the standardized white collar retired male population for the years 1960 through 1984. The overall SMR (1.24) for all causes in the pooled blue collar group (95% C.I. = 1.17, 1.32) was significantly elevated. A significant excess in overall mortality was also seen for both the all cancers (SMR = 1.45; 95% C.I. = 1.29, 1.63) and circulatory diseases (SMR = 1.23; 95% C.I. = 1.13, 1.34) categories.

Age-Specific SMR Analyses of the Pooled Blue Collar Male Population

Table 17 displays the three principal contributors to mortality for the pooled blue collar male cohort by 5-year age-bands for ages 50 to 85, and older. For all causes in the pooled blue collar group the age-specific SMRs were significantly elevated in age-bands 50-54

TABLE 17

Standardized Mortality Ratios (SMR) for All and Selected Causes of Death by Five-Year Age Bands for Combined Hourly Population Versus Standardized Salaried Population as a Comparison Group

		All Causes			All Cancers			Circulatory Diseases				
		O / E	SMR	95% C.I.	O / E	SMR	95% C.I.	O / E	SMR	95% C.I.		
50-54	24	12.04	1.99	** 1.28,2.96	9	4.01	2.24	** 1.02,4.23	11	1.34	8.22	** 4.10,14.65
55-59	93	40.37	2.30	** 1.86,2.82	37	10.42	3.55	** 2.50,4.89	30	22.14	1.36	0.91,1.93
60-64	177	165.00	1.07	** 0.92,1.24	55	34.50	1.59	** 1.20,2.08	75	73.50	1.02	0.80,1.28
65-69	309	266.19	1.16	** 1.04,1.30	88	67.37	1.31	** 1.05,1.61	155	138.03	1.12	** 0.95,1.31
70-74	269	213.45	1.26	** 1.11,1.42	60	51.64	1.16	0.89,1.50	139	111.89	1.24	** 1.04,1.24
75-79	136	139.61	0.97	0.82,1.15	31	26.69	1.16	0.79,1.65	83	71.86	1.16	0.92,1.43
80-84	67	67.65	0.99	0.77,1.26	10	13.01	0.77	0.37,1.41	36	28.62	1.26	** 0.88,1.74
85+	8	17.57	0.46	0.20,0.89	2	2.51	0.80	0.09,2.43	3	12.55	0.24	** 0.05,0.65
Overall	1083	871.44	1.24	** 1.17,1.32	292	201.23	1.45	** 1.29,1.63	532	433.29	1.23	** 1.13,1.34

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*ICD-8, International Classification of Diseases, Eighth Revision.

+ Based on rates for standardized white males population, adjusted for age and calendar year.

+ + Fisher's exact confidence limits.

** Statistically significant ($P < 0.05$).

(SMR = 1.99; 95% C.I. = 1.28, 2.96), 55-60 (SMR = 2.30; 95% C.I. = 1.86, 2.82), 65-69 (SMR = 1.16; 95% C.I. = 1.04, 1.30), and 70-74 (SMR = 1.26; 95% C.I. = 1.11, 1.42). These results were generally similar to what has been seen in the blue collar cohort throughout this study. The remaining age-bands 60-64 (SMR = 1.07; 95% C.I. = 0.92, 1.24), 75-79 (SMR = 0.97; 95% C.I. = 0.82, 1.15), and 80-84 (SMR = 0.99; 95% C.I. = 0.77, 1.26) exhibited mortality consistent with standardized values. However, the 85 and older age-band (SMR = 0.46; 95% C.I. = 0.20, 0.89) showed a significantly decreased SMR (0.46) in the all causes category. The significant deficit was based on 8.00 observed deaths, versus 17.57 expected. Little inference could be made regarding this finding since no other consistent association emerged from this deficit.

Mortality rates were significantly elevated for all cancers in the age-bands 50-54 (SMR = 2.24; 95% C.I. = 1.02, 4.23), 55-59 (SMR = 3.35; 95% C.I. = 2.50, 4.89), 60-64 (SMR = 1.59; 95% C.I. = 1.20, 2.08), and 65-69 (SMR = 1.31; 95% C.I. = 1.05, 1.61). Caution must be used when interpreting the statistical significance of the finding associated with the age-band 50-54. The excess mortality was based on 9.00 observed deaths versus 4.01 expected deaths. SMRs for the age-bands 70-74 (SMR = 1.16; 95% C.I. = 0.88, 1.50) and 75-79 (SMR = 1.16; 95% C.I. = 0.79, 1.65) were representative of the standardized group. The two remaining age-bands 80-84 (SMR = 0.77; 95% C.I. = 0.37, 1.41) and 85 and older (SMR = 0.80; 95% C.I. = 0.09, 2.43) exhibited deficit SMRs. However, only limited inferences, if any, can be drawn regarding these deficits due to the fact that no consistent associations with the previous age-bands emerged.

Mortality from circulatory diseases did not follow the significant excess death pattern that was seen in the all causes and all cancers categories. Moreover, SMRs were significantly

elevated only in the 50-54 (SMR = 8.22; 95% C.I. = 4.10, 14.65) and 70-74 (SMR = 1.24; 95% C.I. = 1.04, 1.24) age-bands.

Here again, the number of deaths observed (11.00) versus the number of deaths expected (1.34) was considered by this researcher not to be sufficient enough to provide adequate statistical power. Other age-bands 55-59 (SMR = 1.36; 95% C.I. = 0.91, 1.93), 60-64 (SMR = 1.02; 95% C.I. = 0.82, 1.28), 65-69 (SMR = 1.12; 95% C.I. = 0.95, 1.31), 75-79 (SMR = 1.16; 95% C.I. = 0.92, 1.43), and 80-84 (SMR = 1.26; 95% C.I. = 0.88, 1.74) exhibited mortality consistent with standardized values. Only in one instance were SMRs less than unity for circulatory diseases. In fact, the SMR (0.24) for the age-band 85 and older (95% C.I. = 0.05, 0.65) was significantly low. However, the significant deficit was based on 3.00 observed deaths versus 12.55 expected.

Generalizations Regarding the Mortality Experience of the Pooled Blue Collar Male Population When Directly Compared to a Pooled Standardized White Collar Male Population and Hypotheses Outcomes

1. A consistent pattern of elevated mortality emerged from the results of SMR analyses for all causes combined and all cancers combined within the 50-69 age-groups.
2. Mortality for all causes combined and circulatory diseases was significantly higher than the standardized values.
3. The total overall mortality within the blue collar population was significantly elevated for all causes combined, all cancers combined, and circulatory diseases when compared to a standardized white collar population (see Table 17).
4. There was no apparent HWE in the pooled blue collar population when it is compared to the standardized white collar population.

Null hypothesis-5 (there will be no differences in survivorship and mortality experience for the combined hourly male populations from ORNL, ORGDP, and Y-12 when compared to a standardized white collar population from the same facilities for diabetes, all respiratory diseases, cirrhosis of the liver, genito-urinary diseases, accidents, and suicide) was accepted. The number of deaths observed from these causes was generally as expected.

The acceptance of alternative hypothesis-5 (excess in death rates will be seen for the combined hourly populations of ORNL, ORGDP, and Y-12 when compared to a standardized white collar population from the same facilities for all causes, all cancers, circulatory diseases [i.e., cardiovascular and cerebrovascular diseases combined], and diseases of the digestive system) is consistent with the previous male findings in this study; that is, socioeconomic status has a profound impact on male longevity in this study population.

Discussion

This portion of the retrospective cohort study described the mortality experience of white males who retired from government facilities in Oak Ridge, Tennessee between 1960 and 1979. This study of retirees presented a problem that is common to most retiree studies, i.e., the effect of small sample size. Although an attempt was made to increase the sample size by pooling the plant-specific subcohorts and separating the combined populations into blue collar (hourly) and white collar (salaried) groups, one must be aware that there is always a risk of diluting significant findings among subgroups whenever cohorts are pooled.

It has been demonstrated in other cohort studies that mortality patterns can vary among people of different economic classes (Kilpatrick, 1963; Antonovsky, 1967; and Nagi and Stockwell, 1973). Moreover, the higher the socioeconomic status, the lower the general overall mortality (Wen, Tsai, and Gibson, 1983). If socioeconomic status is a powerful

determinant of mortality and significantly contributes to the HWE during one's employment years, then it stands to reason that a carry-over in this improved health status should last for some duration in one's post-retirement years.

Salaried Male Population

The results of this investigation indicate that the overall mortality experiences of the male retirees from DOE-Oak Ridge were divided along two distinct relative risk pathways. The relative risk pathways were linked to age and job status (socio-economic status) at the time of retirement. For example, the salaried white male retired population had an overall mortality experience generally better than or consistent with that of the U.S. population for all major causes of death, including all cancers and all circulatory diseases. This finding was likely attributable to the HWE. This phenomenon is usually associated with physically demanding activities (e.g., jogging, swimming, etc.) and as such, it is likely that individuals from the higher socioeconomic groups preferred and practiced a more healthy lifestyle.

Another reason that may have caused overall mortality in the pooled salaried male population to be lower than expected is that job security and employee mobility appeared to be more favorable for the salaried group and, therefore, reduced the likelihood of stress-related ailments such as coronary heart disease and hypertension. Perhaps the ability to cope with stress positively impacted both the physical and mental health of salaried persons during their post-retirement years.

Yet another explanation for the decrements noted in the overall categories for all causes, all cancers, and diseases of the circulatory system in the pooled salaried male retirees is that the large majority of white collar jobs had low exposure potential to radiation or to nonradioactive substances (e.g., heavy metals, organic solvents, and other noxious chemicals).

Tobacco use (i.e., smoking) was also a contributor to overall mortality in the salaried cohort. This is supported by the fact that the overall number of both malignant and nonmalignant diseases of the respiratory system was essentially as expected.

While the overall mortality experience of the salaried male cohort was less than or comparable to that of the U.S., some variation was found in cause-specific experience. Analysis based on grouping of mortality rates into 5-year age-at-death intervals had an effect on mortality outcome. When the salaried male population at each facility was stratified by age at death and cause of death following retirement, several new observations were made.

The ratios of age-specific mortality rates for all causes, all cancers, and circulatory diseases by 5-year age-bands tended to vary over a greater range, but the majority of ratios were less than unity. In general, salaried retirees did not have a mortality experience significantly different than that of the U.S. population, whereas the hourly retirees did. Among salaried male retirees from each facility who fell within the 65-69 and 70-74 age-bands, the observed number of deaths for all causes, all cancers, and circulatory diseases was lower than expected (the Y-12 population for all cancers was the exception; an SMR of 1.00 was found in the age-band 70-74). This finding suggests that, within the context of normal retirement, there is a favorable carry-over in health status for salaried male retirees.

Perhaps the two principal contributing factors for carry-over in the HWE were timing and degree of control that a retiree had over his retirement. These salaried males more than likely represent a group of retirees who had enjoyed the benefits of long-term medical follow-up and treatment associated with career employment at the DOE-Oak Ridge facilities.

The significantly elevated number of deaths in the Y-12 salaried group age-band 60-64 for all causes and all cancers was probably the result of time-related exposure risk. Table 18 provides an overview of the total number of cancer deaths by specific category that were

TABLE 18

Enumeration of Cancer Deaths by Site-Specific Category and Pay Status for White Male Retirees, 1960-1984.

Category	ICD-8th	Hourly	Salaried	Total	
				Deaths	Percent of Total
All Cancers	140-209	292 (70%)	124 (30%)	416	100%
Buccal Cavity & Pharynx	140-149	4 (0.96%)	0 (0%)	4	0.96%
Digestive Organs and Peritoneum*	150-159	64 (15.0%)	32 (7.69%)	96	23%
Larynx	161	5 (1.20%)	0 (0%)	5	1.20%
Lung*	162-163	123 (30%)	51 (12%)	174	42%
Connective Tissue	171	2 (0.48%)	0 (0%)	2	0.48%
Skin	172-173	5 (1.20%)	3 (0.72%)	8	1.92%
Prostate*	185	28 (6.73%)	16 (3.85%)	44	10.58%
Testis	186-187	1 (0.24%)	0 (0%)	1	0.24%
Bladder	188	9 (2.16%)	3 (0.72%)	12	2.88%
Kidney	189	5 (1.20%)	2 (0.48%)	7	1.68%
Brain and CNS	191-192	6 (1.44%)	3 (0.72%)	9	2.16%
Ill-Defined Site	195	2 (0.48%)	0 (0%)	2	0.48%
Secondary Respiratory and Digestive System	197	2 (0.48%)	3 (0.72%)	5	1.20%
Other Secondary Cancers	198	3 (0.72%)	2 (0.48%)	5	1.20%
Without Specification of Site	199	11 (2.64%)	3 (0.72%)	14	3.37%
All Lymphopoietic Cancers	200-209	22 (5.29%)	6 (1.44%)	28	6.73%

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*Specific cancers selected for further investigation.

found in the salaried male population. As can be seen in Table 18, specific sites for all digestive organs, lungs, and cancers of the prostate contributed to the vast majority (76%) of cancer deaths. Further analysis is focused on the salaried male retirees who died from these cancers. Table 19 displays the SMRs for retirees by 5-year age-bands for the causes of death that have been chosen for further investigation.

The overall number of observed deaths for digestive cancers in the salaried male retiree group was less than expected for ORGDP (SMR = 0.50) and ORNL (SMR = 0.80); however, these deficits were not statistically significant. The ratio of overall number of observed to expected deaths for digestive cancers was unity for the Y-12 male retirees. These deficit findings were somewhat unexpected because in older persons (65 and older), digestive cancer becomes more common and accounts for substantial in the general population mortality (Smith, 1987). The lower-than-expected number of digestive cancers was largely responsible for the overall deficit findings in the all cancers category. Moreover, these deficit findings are probably attributed to the cohort's better-than-average income level and their greater access to health care during their employment years.

Conversely, the overall number of observed deaths for cancer of the prostate was slightly higher than expected for retired salaried males of ORGDP (SMR = 1.21), ORNL (SMR = 1.20), and Y-12 (SMR = 1.58); however, these elevations were not statistically significant. The nonsignificant elevation in the expected number of deaths from prostate cancer was not altogether surprising because extensive medical examinations provided as a free service at each of the Oak Ridge facilities probably resulted in early detection and treatment of this disease.

Although little is known about the aetiology of the disease, two suspected factors are predominate in current literature. The first factor concerns elevated levels of testosterone

TABLE 19 (continued)

Standardized Mortality Ratios (SMR) for Cancers of the Lungs, Digestive Organs, and Prostate Among Salaried Male Retirees of ORNL, ORGDP, and Y-12

	Digestive Organs (150-159)				Y-12			
	ORNL		ORGDP		Y-12			
	O / E ⁺	SMR 95% C.I. ⁺⁺	O / E ⁺	SMR 95% C.I. ⁺⁺	0 / E ⁺	SMR 95% C.I. ⁺⁺	0 / E ⁺	SMR 95% C.I. ⁺⁺
50-54	0 0.13	- , -	0 0.09	- , -	0 0.05	- , -	0 0.05	- , -
55-59	0 0.68	- , -	1 0.59	1.69	2 0.37	5.35	2 0.37	5.35
60-64	2 1.97	1.02	0 1.72	- , -	6 1.44	4.17	6 1.44	4.17
65-69	7 4.57	1.53 0.61,3.16	2 4.15	0.48	3 4.11	0.73 0.15,2.13	3 4.11	0.73 0.15,2.13
70-74	2 3.38	0.59 0.07,2.14	1 3.30	0.30	2 3.18	0.63 0.07,2.27	2 3.18	0.63 0.07,2.27
75-79	0 1.44	- , -	1 1.51	0.66	1 1.47	0.68	1 1.47	0.68
80-84	0 0.39	- , -	1 0.55	1.83	1 0.40	2.53	1 0.40	2.53
85+	0 0.04	- , -	0 0.11	- , -	0 0.05	- , -	0 0.05	- , -
Overall	11 12.60	0.87 0.44,1.56	6 12.02	0.50	15 15.07	1.00 0.56,1.64	15 15.07	1.00 0.56,1.64

*ICD-8, International Classification of Diseases, Eighth Revision.

⁺Based on rates for U.S. white males, adjusted for age and calendar year.

⁺⁺Fisher's exact confidence limits.

-Less than two deaths expected.

Continued on next page

TABLE 19 (continued)

Standardized Mortality Ratios (SMR) for Cancers of the Lungs, Digestive Organs, and Prostate Among Salaried Male Retirees of ORNL, ORGDP, and Y-12

	ORNL			Prostate (185)			Y-12		
	O / E ⁺	SMR	95% C.I. ⁺⁺	O / E ⁺	SMR	95% C.I. ⁺⁺	O / E ⁺	SMR	95% C.I. ⁺⁺
50-54	0	0.01	-	0	0.01	-	0	0.00	-
55-59	0	0.08	-	0	0.07	-	0	0.04	-
60-64	0	0.38	-	0	0.32	-	1	0.27	3.66
65-69	1	1.28	0.78	0	1.15	-	4	1.15	3.48
70-74	3	1.35	2.22	3	1.30	2.30	1	1.26	0.79
75-79	1	0.78	1.29	2	0.81	2.49	0	0.78	-
80-84	0	0.27	-	0	0.37	-	0	0.27	-
85+	0	0.03	-	0	0.09	-	0	0.04	-
Overall	5	4.18	1.20	5	4.12	1.21	6	3.81	1.58
			0.39,2.73			0.39,2.77			0.58,3.38

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*ICD-8, International Classification of Diseases, Eighth Revision.

⁺Based on rates for U.S. white males, adjusted for age and calendar year.

⁺⁺Fisher's exact confidence limits.

-Less than two deaths expected.

and/or dihydrotestosterone over many years which can lead to prostate gland hyperplasia and carcinoma (Ghanadian, et al., 1979 and Ahluwalia, et al., 1981). High fat consumption over several years is the second factor thought to elevate the risk of prostate cancer. Both hypotheses support McMichael's (1976) postulation that the survival advantage conferred by the HWE declines as a given cohort ages. More importantly, however, is the fact that the SMRs for prostate cancer are not significantly different than 1.00. This is an indication that lifestyle factors (e.g., diet) in this cohort were essentially about the same as those of the blue collar study population.

The overall number of observed deaths from lung cancer was slightly higher than expected for retired salaried males of ORGDP (SMR = 1.10) and Y-12 (SMR = 1.27). These elevations were not statistically significant. The overall number of observed deaths from lung cancer was non-significantly lower than expected for retired salaried males of ORNL (SMR = 0.80).

Cancer of the lung is known to be related to tobacco use. The overall increase for lung cancer in the ORGDP and Y-12 populations was probably attributed to the individuals within these groups smoking tobacco products over a protracted period of time. The National Cancer Institute estimates that about 30% of all cancers could be eliminated if people quit smoking (Office of Smoking and Health, 1982). Cigarette consumption among U.S. men reached an all time high between 1940 and 1964 and did not change materially until 1964 when a comprehensive report from the Surgeon General's office showed the dose-response relationship between the amount smoked and the risk of lung cancer (DHHS, 1982). Since that time the incidence of lung cancer in white males has slowed gradually.

Although medical records were not accessed for this study, it was hypothesized by this researcher that mortality from all cancers would be slightly elevated in the salaried males

across all the DOE-Oak Ridge facilities. Hence, the smoking habits of the ORGDP and the Y-12 salaried male cohorts may explain the slight increase in lung cancer. Lung cancer in the ORNL salaried cohort was a primary contributory cause in deficit mortality for the all cancers category. The relatively small proportion of the total deaths observed from lung cancer is a strong indication that tobacco usage in the ORNL salaried male population was far below what is expected when compared to a similar segment of the U.S. population.

In the early 1980s lung cancer had become the most common cancer in the U.S. It now accounts for 25% all cancer deaths in America (Health-United States, 1988). Cigarette smoking is securely established as the principal cause of lung cancer in the U.S. However, the basic mechanism by which a normal cell becomes malignant is still unknown (Vessey and Gray, 1985).

For the salaried retirees of this study population, the observed number of deaths from lung cancer was essentially as expected for ORGDP and Y-12. However, the mortality ratio was lower than expected for the ORNL salaried male population. None of the mortality ratios for lung cancer from the three plants was statistically significant. Hence, it is possible that differences in health-related behavior (e.g., smoking) among retirees of the three plant sites may have contributed to their generally favorable mortality experiences. This evidence does not incriminate smoking as a major contributor to cancer mortality in the salaried male populations of ORGDP and ORNL.

The absence of an overall excess of nonmalignant respiratory disease mortality at ORGDP (SMR = 0.79) and ORNL (SMR = 0.71) for the male salaried population is indirect evidence that the smoking habits of this cohort were not excessive. However, when augmented by a higher-than-expected mortality rate for malignant respiratory diseases, the statistically significant increase in nonmalignant respiratory disease for Y-12

(SMR = 1.65) salaried males indicates that tobacco use may have been heavy in this group (see Table 20).

The overall use of alcohol appears to be moderate in the salaried cohort because of the nonsignificant excess in mortality from cirrhosis of the liver across the facilities (ORGDP, SMR = 1.30; Y-12, SMR = 1.08; ORNL, SMR = 2.06). This finding is also supported by the fact that there were no deaths from esophageal cancer found in the total salaried male cohort.

The results from the analyses of mortality experience among the retired salaried population, by facility and by pooled salaried cohort, showed that some slightly elevated SMRs could be of biological importance even though they were not statistically significant. The salaried males analyses results, taken together with other evidence in the literature from mortality studies, support the hypothesis that the event of retirement does not put white collar men at risk of health deterioration. The results of the salaried male analyses also partially support the conclusion drawn by McMichael (1976) that carry-over in the HWE in post-retirement declines with age, and retirees increasingly come to resemble the general population in their health status characteristics. However, the results of this study do not support the McMichael (1976) finding that, within the retirees aged 65-84, the HWE no longer operates effectively. White collar males who retired from the DOE-Oak Ridge facilities generally had overall mortality rates lower than that of the U.S. within the age-range 65-84. Hence, the residual survival advantage still appeared to be active after 29 years of observation in the salaried male population.

One would suspect SMRs to be less than 1.00 in the earlier age-bands (i.e., 50-64) and to approach or exceed 1.00 as the population aged. In other words, the longer the follow-up, the more noticeable the mathematical increase in SMRs. Wen, et al. (1983), referred to this

TABLE 20

Standardized Mortality Ratios (SMR) for Nonmalignant Respiratory system Diseases, Malignant Respiratory Diseases, and Cirrhosis of the Liver Among Salaried Male Retirees of ORNL, ORGDP, and Y-12 Plant.

	All Respiratory System Diseases (nonmalignant) (460-519)*			All Malignant Respiratory System Diseases (160-163)*			Cirrhosis of Liver (571)*					
	O / E ⁺	SMR	95% C.I. ⁺⁺	O / E ⁺	SMR	95% C.I. ⁺⁺	O / E ⁺	SMR	95% C.I. ⁺⁺			
ORNL	11	15.43	0.71	0.36-1.27	14	18.24	0.77	0.42-1.28	7	3.40	2.06	0.83-4.19
ORGDP	12	15.13	0.79	0.41-1.38	18	16.58	1.09	0.64-1.71	4	3.07	1.30	0.35-3.22
Y-12	23	13.94	1.65	1.05-2.47	19	15.58	1.22	0.73-1.90	3	2.79	1.08	0.22-2.95
Overall	46	44.50	1.03	0.76-1.38	51	50.40	1.01	0.75-1.33	14	9.26	1.51	0.83-2.53

*ICD-8, International Classification of Diseases, Eighth Revision.

⁺Based on rates for U.S. white males, adjusted for age and calendar year.

⁺⁺Fisher's exact confidence limits.

**Statistically significant ($P < 0.05$).

occurrence as an inverse relationship between SMR and life expectancy when the study cohorts' mortality is similar to that of the U.S.

The results of these analyses support McMichael's (1976) postulation that, in terms of pathologic processes, diseases that usually cause excess mortality after retirement will be seen more readily in those individuals who take early retirement. Presumably, early retirement in many instances is a form of out-selection of the less healthy workers. Therefore, one might expect to see a marked decline in carry-over in the HWE in those persons retiring early (i.e., ages 50-64); assuming, of course, there was a HWE during their employment.

This supposition is further supported in recent research findings by Boaz and Muller (1990). They found in a Social Security Administration self-reported longitudinal retirement history survey that mortality is more pronounced for early retirees (i.e., those retiring before age 65) than for normal retirees (i.e., those retiring at age 65 or older). They also found that men who report health problems after they retire are much more likely to have used more medical care at the time of retirement and are more likely to die within 2 years of leaving the workforce than men reporting no such problems when retiring. Boaz and Muller's findings were based on 8,132 men interviewed in 1969 and were followed up biennially until 1979. They noted that mortality was consistently more elevated in those men who retired early.

Part A of Table 21 provides additional evidence that those individuals who left the workforce before the age of 62 sustained the greatest number of deaths. Of the 1,620 total deaths recorded in the male study population, 43% (694) occurred in the 62-and-under age-group; 24% (395) occurred in the 62-64 age-group; and 33% (531) occurred in the 65-and-older age-group. Of the 531 deaths recorded for those individuals with retirements ages of

Table 21

Enumeration in The Age-Specific Growing of the Number of Deaths for White Males by Pay Code and Age at Retirement: 1960-1979.

Part A

Age	Facility	Pay Code		Total	Percent of Total	
		Hourly	Salaried			
<62	ORNL	61	79	140	9%	43%
	ORGDP	201	86	287	18%	
	Y-12	203	64	267	16%	
	Subtotal	465	229	694		
62-64.9	ORNL	52	30	82	5%	24%
	ORGDP	98	47	145	9%	
	Y-12	125	43	168	10%	
	Subtotal	465	229	694		
≥65	ORNL	97	65	162	10%	33%
	ORGDP	92	58	150	9%	
	Y-12	154	65	219	14%	
	Subtotal	343	188	531		
Total		1,083	537	1,620	100%	

Table 21 (Continued)

Enumeration in The Age-Specific Growing of the Number of Deaths for White Males by Pay Code and Age at Retirement: 1960-1979.

Part B
Hourly Male Retirees
All Causes*

Retirement Group (Yrs.)	Age	Observed	Expected+	SMR	95% C.I.++
65 and older	65	100	118.65	0.84	0.69-1.03
	70	110	125.57	0.88	0.72-1.06
	75	82	90.78	0.90	0.72-1.12
	80	45	45.41	0.99	0.72-1.33
	85	6	10.46	0.57	0.21-1.25
62 to 64.9	62	37	37.70	0.98	0.69-1.35
	65	98	121.15	0.81	0.66-0.99**
	70	86	91.21	0.94	0.75-1.17
	75	34	43.34	0.79	0.54-1.10
	80	18	15.17	1.19	0.70-1.88
	85	2	2.52	0.80	0.09-2.87
Before 62	50	24	6.78	3.54	2.27-5.27**
	55	93	35.62	2.61	2.11-3.20**
	60	140	81.66	1.71	1.44-2.02**
	65	111	76.78	1.45	1.19-1.74**
	70	73	48.63	1.50	1.18-1.88**
	75	20	20.85	0.96	0.59-1.48
	80	4	7.36	0.54	0.15-1.39
	85	0	0.17	0	-

*ICD-8, International Classification of Disease, Eighth Revision

+Based on rates for U.S. white males, adjusted for age and calendar year.

++Fisher's exact confidence limits.

**Statistically significant ($P < 0.05$).

Table 21 (Continued)

Enumeration in The Age-Specific Growing of the Number of Deaths for White Males by Pay Code and Age at Retirement: 1960-1979.

Part C
Salaried Male Retirees
All Causes*

Retirement Group (Yrs.)	Age	Observed	Expected+	SMR	95% C.I.++
65 and older	65	59	76.27	0.77	0.59-1.00
	70	63	79.65	0.79	0.61-1.01
	75	41	48.42	0.85	0.61-1.15
	80	18	19.25	0.94	0.55-1.48
	85	7	4.83	1.45	0.58-2.99
62 to 64.9	62	24	17.04	1.41	0.90-2.10
	65	45	59.85	0.75	0.55-1.01
	70	29	43.83	0.66	0.44-0.95**
	75	16	17.15	0.93	0.53-1.52
	80	6	5.34	1.13	0.41-2.45
	85	0	0.41	0.	-
Before 62	50	9	4.89	1.84	0.84-3.49
	55	31	26.30	1.18	0.80-1.67
	60	86	60.51	1.42	1.14-1.76**
	65	58	63.67	1.08	0.82-1.40
	70	32	29.22	1.10	0.75-1.55
	75	11	9.89	1.11	0.56-1.99
	80	2	1.62	1.24	-
	85	0	0	0	-

*ICD-8, International Classification of Disease, Eighth Revision

+Based on rates for U.S. white males, adjusted for age and calendar year.

++Fisher's exact confidence limits.

**Statistically significant ($P < 0.05$).

65 and older, 65 percent (343) were blue collar. Overall, the hourly population represented 65% (1,083) of the 1,620 deaths recorded in the male cohort.

Since Y-12 had the largest number of blue collar retirees, it was not surprising to find that the greatest proportion of the recorded hourly deaths came from that facility (45%, or 482 persons). These data suggest that a large number of individuals in the male cohort had little control over their retirement. Also, these data imply that those persons who retired early may have left (i.e., selected out) the workforce because of their deteriorating health status.

When the male study population was analyzed by pay status and retirement age the results provided further evidence that individuals retiring before age 62 are at an elevated risk of mortality from all causes. In the case of the blue collar cohort, the mortality risk from all causes is significantly elevated in those retiring before age 62.

Table 21, Part B, shows that the statistically significant elevated findings in the blue collar male subgroup of previous analyses was principally attributed to the hourly males who retired before age 62. Hourly males who retired at age 65 (normal retirement age) exhibited death rates lower than expected when compared to the general population. SMRs for all causes are lower than expected for age 65 ($SMR = 0.85$), but increased at ages 70 ($SMR = 0.88$), 75 ($SMR = 0.90$), and 80 ($SMR = 0.99$). However, SMRs were inexplicably low for ages above 80 ($SMR = 0.57$). Once again, this finding suggests that the HWE actively continues for a protracted period of time following retirement.

With the exception of age 80 ($SMR = 1.19$), hourly males who retired between the ages of 62 and 64 had lower-than-expected SMRs. When the hourly male subgroup was analyzed by retirement ages younger than 62, mortality observations were quite different. In fact, those blue collar males who retired before age 62 showed statistically significant elevated

death rates for the ages of 50 (SMR = 3.54), 55 (SMR = 2.61), 60 (SMR = 1.71), 65 (SMR = 1.45), and 70 (SMR = 1.50). Although the significantly elevated trend continued downward with age, not until this subgroup reached age 75 (SMR = 0.96) did the significant risk of mortality from all causes totally diminish.

Lower-than-expected values were also seen for age 80 (SMR = 0.54). Deteriorating health status has been shown in other research to be the prime causal factor for early retirement. It can also be incriminated for the statistically significant elevation in the death rates for this age group. The possible explanations for these adverse findings in the hourly male retired cohort are discussed later in this chapter.

Part C of Table 21 shows that salaried male retirees who retired at age 65 exhibited death rates lower than the general population for all causes. Mortality for all causes was lower than expected for age 65 (SMR = 0.77). A gradual increase in SMRs was seen at age 70 (SMR = 0.79) and continued to increase of age 75 (SMR = 0.85) and age 80 (SMR = 0.94). Not until age 85 (SMR = 1.45) did the death rate rise.

The lower-than-expected death rates can be attributed to the carry-over in the HWE. With the exception of age 60 (SMR = 1.41), the individuals in the salaried group retiring between the ages 62 and 64 had mortality rates similar to those of the people who retired at age 65. However, when those individuals who retired before age 62 were examined, their death rates were never less than unity. The all causes mortality excesses for ages 50 (SMR = 1.84), 55 (SMR = 1.18), 60 (SMR = 1.42), 65 (SMR = 1.08), 70 (SMR = 1.10), 75 (SMR = 1.11), and 80 (SMR = 1.24) suggest that those individuals who retired before age 62 were at a greater risk of mortality than other salaried male retirees. Moreover, the implication can be made that these persons had virtually no control over their retirement if, in fact, failing health was the reason for their leaving the workforce.

Generally speaking, it appears that the overall survival in the salaried males was congruent with that of the U.S. population. This finding is also supported by the fact that the vast majority of deaths (61%) in the salaried population occurred within a time period that was equal to or greater than 5 years following retirement (see Table 22). Ninety percent of the individuals in this group were age 65 and older, which suggests that salaried males who retired at normal retirement age (65 years) had a 9:1 chance of living to an age commensurate to that of the general U.S. male population (72 years).

Moreover, according to the way this study population was chosen, an individual had to live at least 5 years to get into the bottom four age-bands (i.e., 70-74, 75-79, 80-84, and 85 and older). As a result, the age-band 70-74 represented 5 additional years of life following retirement; the 70-79 age-band represented 10 years lived following retirement; the age-band 80-84 represented 15 years of life after retirement; and the age-band 85 and older represented 20 additional years of life following retirement. This group (70-85, and older) constituted a sizable proportion of persons who lived at least 5 years beyond their retirement from the DOE-Oak Ridge facilities (i.e., ORNL = 54/105, or 51%; ORGDP = 86/119, or 72%; and Y-12 = 75/102, or 74%). These data, for the most part, imply that life expectancy for the salaried population was generally better than that for the U.S. population for those persons who lived 5 or more years beyond retirement from the facilities being investigated.

Hourly Male Population

Unlike the salaried male population, the blue collar retirees, when compared to the U.S. population, exhibited significantly elevated overall mortality for all causes (SMR = 1.11 cumulative) and all cancers (SMR = 1.27 cumulative). Because of potential carry-over in the HWE in post retirement, it was unexpected to find these categories of death significantly elevated. One possible explanation for excess mortality in the hourly male group is that death

TABLE 22

Number of Days Lived Following Retirement in the ORNL Salaried Population

Age	Survival Time (days)								Total	
	30-89	90-179	180-299	300-729	730-1459	1460-1824	≥ 1825		Dead	
50-54	1	0	0	1	3	0	0		5	
55-59	0	0	0	2	5	0	2		9	
60-64	2	3	0	4	9	6	18		36	
65-69	0	0	1	5	14	13	27		60	
70-74	0	0	0	0	0	0	38		38	
75-79	0	0	0	0	0	0	17		17	
80-84	0	0	0	0	0	0	7		7	
85+	0	0	0	0	0	0	2		2	
Total										136
Dead	3	3	1	12	31	19	105		174	

Continued on next page

TABLE 22 (continued)

Number of Days Lived Following Retirement in the ORGDP Salaried Population	Survival Time (days)							Total	
	Age	30-89	90-179	180-299	300-729	730-1459	1460-1824	≥ 1825	Dead
	50-54	0	2	0	2	0	0	0	4
	55-59	3	1	0	3	4	0	0	11
	60-64	4	1	1	4	9	5	11	35
	65-69	2	0	2	5	16	8	22	55
	70-74	0	0	0	0	0	0	42	42
	75-79	0	0	0	0	0	0	29	29
	80-84	0	0	0	0	0	0	11	11
	85+	0	0	0	0	0	0	4	4
Total		9	4	3	14	29	13	119	191
Dead									

Continued on next page

TABLE 22 (continued)

Number of Days Lived Following Retirement in the Y-12 Salaried Population

Age	Survival Time (days)							Total	
	30-89	90-179	180-299	300-729	730-1459	1460-1824	≥ 1825	Dead	
50-54	0	0	0	0	0	0	0	0	
55-59	0	1	0	5	2	2	1	11	
60-64	2	3	2	12	9	5	6	39	
65-69	0	0	2	6	13	6	20	47	
70-74	0	0	0	0	0	0	44	44	
75-79	0	0	0	0	0	0	22	22	
80-84	0	0	0	0	0	0	8	8	
85+	0	0	0	0	0	0	1	1	
Total									138
Dead	2	4	4	23	24	13	102	172	

Continued on next page

rates may have been driven upward by persons in this population who left the workforce before normal retirement age (i.e., < age 65). Another possible explanation for excess mortality in the blue collar population may be attributed partly to a selection bias during the initial hiring of the cohort. Many workers hired during the World War II (WWII) era of the DOE-Oak Ridge operations were either too old or physically unfit to serve on active military duty. As a result, much of the initial blue collar workforce (predominantly semi-skilled and unskilled with no formalized education) in the Oak Ridge government facilities would have been screened out as unemployable under normal circumstances. This phenomenon has been observed in other cohorts employed during the WWII era (Wen, et al., 1986 and Dupree, et al., 1987).

As displayed in Table 23, 62% (1989 persons) of the total 3,196 hourly employees included in this study were hired before January 1, 1950. These data provide further evidence that the HWE probably did not actively operate in a large proportion of the blue collar male population because of their less-than-superior health status on date of hire.

To dismiss these findings of significantly elevated mortality in the Oak Ridge blue collar retired population as being largely attributable to the absence of the HWE is quite tempting, but is perhaps much too simplistic. One would be naive to assume that selection of unhealthy blue collar males for employment is the principal causal factor for significantly elevated mortality in this group. As shown in Table 23, the mortality experience of the males who were hired on or before January 1, 1950, is essentially the same (i.e., before January 1, 1950 = 40%; after January 1, 1950 = 34%) as those individuals hired prior to this date. Therefore, a more plausible explanation may be attributed more to an individual's lifestyle than to his health status when hired.

TABLE 23

Number of Observed Deaths for Two Different Cut-Off Dates for Follow-Up of the Study Population (n=4,444).				
Hire Date	*Pay Code		Total	Percent of Total
	Hourly	Salaried		
Hired before 1/1/50	1989	951	2940	66%
Total and percentage of the number of deaths that occurred in the group hired before 1/1/50	861	328	1189 (40%)	
Hired on or after 1/1/50	1207	297	1504	34%
Total and percentage of the number of deaths that occurred in the group hire on or after 1/1/50	424	80	504 (34%)	
Total study population	3196	1248	4444	100%
Overall number of deaths	1285	408	1693 (38%)	

*These data include both the number of deaths for both the males and females.

Work-related routines may have a long-term negative impact on physical and mental health. Job security and personal actualization from employment may also be contributing factors to the overall enhancement of physical health and mental well-being within a given population of employed persons. For example, many blue collar retirees in this study population may have worked in the same job throughout their careers without a change of venue. Moreover, during the time period of this study (1960-1979), contract negotiations that were held every 3 years between management and the union could have been a prime source of stress for this blue collar cohort. Such stress may have been elevated in the years 1963 and 1970 for this group when strikes caused work stoppage for several weeks. During these periods, stress could have been a prime factor in the increased usage of tobacco and, perhaps, was a factor in the increased consumption of alcohol for the blue collar group.

As demonstrated in Table 24, the hourly male populations of ORGDP (SMR = 1.89) and ORNL (SMR = 1.46) have nonsignificantly higher than expected death rates from cirrhosis of the liver. In the Y-12 hourly male population (SMR = 0.85), deaths from this cause were nonsignificantly lower than expected. These findings suggest that alcohol consumption is not excessive in the blue collar cohort. The fact that no esophageal cancers were recorded in this population is yet another indicator of low-to-moderate use of alcohol. Therefore, it is reasonable to postulate that alcohol consumption did not increase the risk of mortality in the blue collar male cohort.

Although the number of deaths from nonmalignant diseases was essentially as expected, smoking may still be implicated as a principal contributor to mortality in the hourly populations of ORGDP (SMR = 1.60) and Y-12 (SMR = 1.49) because both of these populations had significant excesses in the number of deaths from all malignant respiratory

TABLE 24

Standardized Mortality Ratios (SMR) for Nonmalignant Respiratory system Diseases, Malignant Respiratory Diseases, and Cirrhosis of the Liver Among Hourly Male Retirees of ORNL, ORGDP, and Y-12 Plant.

	All Respiratory System Diseases (nonmalignant) (460-519)*				All Malignant Respiratory System Diseases (160-163)*				Cirrhosis of Liver (571)*			
	O / E ⁺	SMR	95% C.I.	++	O / E ⁺	SMR	95% C.I.	++	O / E ⁺	SMR	95% C.I.	++
ORNL	19	15.89	1.20	0.72-1.86	24	15.83	1.52	0.97-2.25	4	2.75	1.46	0.39-3.60
ORGDP	29	26.68	1.09	0.73-1.56	**45	28.20	1.60	1.16-2.14	10	5.30	1.89	0.90-3.45
Y-12	37	37.03	0.99	0.70-1.38	**59	39.63	1.49	1.13-1.92	6	7.00	0.85	0.31-1.84
Overall	85	79.60	1.07	0.85-1.32	**128	83.66	1.53	1.28-1.82	20	15.05	1.33	0.81-1.33

*ICD-8, International Classification of Diseases, Eighth Revision.

+ Based on rates for U.S. white males, adjusted for age and calendar year.

++ Fisher's exact confidence limits.

** Statistically significant ($P < 0.05$).

system diseases. The ORNL hourly male population (SMR = 1.52) had only nonsignificant elevations in mortality from this cause.

Table 18 summarizes the number and types of cancers found in the blue collar population. This table supports the theory that the vast majority of cancer deaths (digestive, prostate, and respiratory) can be directly or indirectly linked to lifestyle behaviors. However, the lack of available data on cigarette smoking and alcohol consumption in the blue collar population limits the lifestyle theory as being a significant causal factor of the overall excess cancer findings.

The concerns regarding the overall mortality for the all causes and all cancers categories notwithstanding, a noteworthy finding is that the vast majority (65%) of deaths in the blue collar male population occurred within a period of time equal to or greater than 5 years following retirement. Also, within the blue collar male group whose members died after 5 or more years of retirement, 88% of them were age 65 or older (see Table 25 for the number of days lived following retirement for the hourly population). This finding suggests that, at a minimum, hourly male retirees had life expectancies commensurate with those of the general population. These findings also suggest that, even with an absence of a detectable HWE, blue collar male retirees from the DOE-Oak Ridge facilities experienced significant survival following retirement.

According to the way this study population was chosen, an individual had to live at least 5 years to get into the bottom four age-bands (i.e., 70-74, 75-79, 80-85, and 85 and older). As a result, the age-band 70-74 represented 5 years of additional life following retirement; age-band 75-79 represented 10 additional years of life; the 80-84 age-band represented 15 more years of life after retirement; and the 85 and older age-band represented 20 years lived following retirement. The hourly group (ages 75-85, and older) constituted a

TABLE 25

Number of Days Lived Following Retirement in the ORNL Hourly Population

Age	Survival Time (days)								Total	
	30-89	90-179	180-299	300-729	730-1459	1460-1824	≥ 1825		Dead	
50-54	0	0	1	0	1	0	0		2	
55-59	1	1	0	1	3	1	2		9	
60-64	3	1	0	5	2	1	9		21	
65-69	0	0	2	7	17	10	29		65	
70-74	0	0	0	0	0	0	58		58	
75-79	0	0	0	0	0	0	35		35	
80-84	0	0	0	0	0	0	16		16	
85+	0	0	0	0	0	0	4		4	
Total								144		
Dead	4	2	3	12	23	12	153		210	

Continued on next page

TABLE 25 (continued)

Number of Days Lived Following Retirement in the ORGDP Hourly Population	Survival Time (days)								Total	
	30-89	90-179	180-299	300-729	730-1459	1460-1824	≥ 1825		Dead	
50-54	2	2	2	5	1	0	0		12	
55-59	3	4	2	5	11	1	5		31	
60-64	2	4	1	12	10	4	32		65	
65-69	2	1	1	8	27	8	56		103	
70-74	0	0	0	0	1	0	108		109	
75-79	0	0	0	0	0	0	49		49	
80-84	0	0	0	0	0	0	21		21	
85+	0	0	0	0	0	0	1		1	
Total								145		
Dead	9	11	6	30	50	13	272		391	

Continued on next page

TABLE 25 (continued)

Number of Days Lived Following Retirement in the Y-12 Hourly Population		Survival Time (days)							Total	
		30-89	90-179	180-299	300-729	730-1459	1460-1824	≥ 1825	Dead	Dead
Age										
50-54		1	1	1	4	3	0	0	0	10
55-59		7	8	3	13	14	4	4	4	53
60-64		4	5	3	17	16	11	35	35	91
65-69		2	1	6	16	32	22	62	62	141
70-74		0	0	0	0	0	0	102	102	102
75-79		0	0	0	0	0	0	52	52	52
80-84		0	0	0	0	0	0	30	30	30
85+		0	0	0	0	0	0	3	3	3
Total										146
Dead		14	15	13	50	65	37	288	288	482

sizable proportion of persons who lived at least 5 years beyond their separation from the DOE-Oak Ridge workforce (ORNL = 113/153, or 74%; ORGDP = 179/272, or 66%; and Y-12 = 187/288, or 65%). Table 25 provides an illustration of these numbers. Although the mortality outcome for the hourly population was higher than that of the salaried cohort in terms of total number of deaths, life expectancy for hourly males in the 65 and older group appeared to be slightly better than that of the U.S. population.

While the excess in the number of circulatory deaths (98.71) was the principal reason for the overall mortality experience in the blue collar population to be generally higher than the U.S., other variations in cause-specific mortality were also found to be key factors in pushing up the all causes SMR. Analysis based on grouping of mortality rates into 5-year intervals had an effect on mortality outcome. When the hourly male population at each facility was stratified by age at death and cause of death following retirement, several new observations could be made.

Among blue collar retirees from Y-12 and ORGDP, significantly elevated mortality was found in the 5-year age-bands 50-54, 55-59, and 60-64 for all causes and all cancers (see Table 13). This significantly-elevated pattern was also demonstrated in circulatory diseases over the same age-bands for the ORGDP group. Only in the all cancers category did the ORNL blue collar group show significantly elevated mortality. However, the wide confidence interval (95% C.I. = 1.96, 11.47) suggests that quantitating the relative risk of cancer in the ORNL blue collar age-band 55-59 is relatively unstable. Nevertheless, the finding of elevated cancers in the ORNL blue collar age-band 55-59 can be expressed as having statistical significance (6.00 observed deaths versus 1.12 expected deaths).

Persons suffering from lung disease are more likely to die at an earlier age than are persons suffering from other chronic diseases (Sterling and Weinkam, 1986). As can be seen

in Table 18, the vast majority of cancer deaths across the Oak Ridge sites being investigated are related to respiratory, prostatic, and digestive organ diseases.

Specific sites for all digestive organs, prostate, and lung cancer made up a substantial portion (74%) of the all cancers category (see Table 18). Further analysis was focused on the hourly male retirees who died from these causes. Table 26 displays the SMRs for retirees by 5-year age-bands for the causes of death that were chosen for further investigation.

The overall number of observed deaths for digestive cancers in the hourly male retirees was slightly elevated over the expected mortality rates for ORGDP (SMR = 1.19) and ORNL (SMR = 1.08); however, these elevations were not statistically significant. A statistically significant excess in the number of digestive organ cancers for the age-band 65-69 was found to be responsible for elevated death rates in the ORGDP cohort. Specifically, cancer of the large intestine (O/E = 8/2.42; SMR = 3.03; 95% C.I. = 1.42, 6.51) was the causal factor for the statistically significant increase in the ORGDP population for the age-band 65-69 (data for this age-band is not shown on the table).

Although no convincing evidence has been implicated in this study to suggest that occupational exposure is a principal contributor in cancer deaths, one cannot totally rule out the possibility that the increase in intestinal cancer may be indirectly linked to some given risk of such exposure. However, other studies have implicated diet, not the ambient environment, as a principal determinant of these cancers (Ahluwalia, et al., 1981; Smith, 1987; and Health-United States, 1988).

The socioeconomic variations between the salaried and hourly populations at ORGDP and ORNL were likely indicators of differences in lifestyle. The lifestyle variations between the two populations may have included dietary patterns that were characterized by high fat or fried food intake and were probable causal factors in digestive diseases. The overall

TABLE 26

Standardized Mortality Ratios (SMR) for Cancers of the Lungs, Digestive Organs, and Prostate Among Hourly Male Retirees of ORNL, ORGDP, and Y-12

	ORNL			Lungs (162-163)			ORGDP			Y-12		
	O / E ⁺	SMR	95% C.I. ⁺⁺	O / E ⁺	SMR	95% C.I. ⁺⁺	O / E ⁺	SMR	95% C.I. ⁺⁺	O / E ⁺	SMR	95% C.I. ⁺⁺
50-54	0	0.06	-	2	0.23	8.80	3	0.21	14.04	-	-	-
55-59	4	0.44	9.12	4	1.33	3.01	9	1.43	6.30	-	-	-
60-64	3	1.91	1.57	13	4.37	2.97	16	5.50	2.91	1.66, 4.72	-	-
65-69	8	5.61	1.43	12	9.50	1.26	17	14.26	1.19	0.69, 1.91	-	-
70-74	4	4.24	0.94	6	7.32	0.82	11	10.35	1.06	0.53, 1.90	-	-
75-79	2	2.05	0.98	4	3.20	1.25	3	4.62	0.65	0.13, 1.90	-	-
80-84	0	0.70	-	2	0.89	2.26	0	1.41	-	-	-	-
85+	0	0.11	-	0	0.08	-	0	0.10	-	-	-	-
Overall	21	15.12	1.39	43	26.92	1.60	59	37.88	1.56	1.19, 2.01	-	-

*ICD-8, International Classification of Diseases, Eighth Revision.

⁺Based on rates for U.S. white males, adjusted for age and calendar year.

⁺⁺Fisher's exact confidence limits.

**Statistically significant (P<0.05).

-Less than two deaths expected.

TABLE 26 (continued)

Standardized Mortality Ratios (SMR) for Cancers of the Lungs, Digestive Organs, and Prostate Among Hourly Male Retirees of ORNL, ORGDP, and Y-12

	Digestive Organs (150-159)				Y-12			
	ORNL		ORGDP		Y-12			
	O / E ⁺	SMR 95% C.I. ⁺⁺	O / E ⁺	SMR 95% C.I. ⁺⁺	0 / E ⁺	SMR 95% C.I. ⁺⁺	0 / E ⁺	SMR 95% C.I. ⁺⁺
50-54	0	0.04	-	-	0	0.18	0	0.14
55-59	1	0.28	3.54	-	1	0.98	4	0.92
60-64	0	1.25	-	-	2	3.01	3	3.53
65-69	5	4.14	1.21	0.39,2.82	14	6.96	7	10.15
70-74	4	3.36	1.19	0.32,3.05	5	5.74	5	7.94
75-79	3	1.93	1.56	-	3	2.96	5	4.23
80-84	0	0.82	-	-	0	1.02	2	1.61
85+	0	0.18	-	-	0	0.13	0	0.19
Overall	13	12.00	1.08	0.58,1.85	25	20.98	26	28.71
						1.19		0.91
						0.77,1.76		0.59,1.33

*ICD-8, International Classification of Diseases, Eighth Revision.

+ Based on rates for U.S. white males, adjusted for age and calendar year.

+ + Fisher's exact confidence limits.

** Statistically significant ($P < 0.05$).

-Less than two deaths expected.

Continued on next page

TABLE 26 (continued)

Standardized Mortality Ratios (SMR) for Cancers of the Lungs, Digestive Organs, and Prostate Among Hourly Male Retirees of ORNL, ORGDP, and Y-12

	ORNL			Prostate (185)			Y-12		
	O / E ⁺	SMR	95% C.I. ⁺⁺	O / E ⁺	SMR	95% C.I. ⁺⁺	O / E ⁺	SMR	95% C.I. ⁺⁺
50-54	0	0.00	-	0	0.01	-	0	0.01	-
55-59	0	0.03	-	0	0.10	-	2	0.10	19.42
60-64	0	0.23	-	1	0.55	1.82	0	0.66	-
65-69	1	1.13	0.88	1	1.91	0.52	5	2.82	1.77 0.57,4.13
70-74	2	1.32	1.52	5	2.26	2.21	2	3.15	0.64 0.07,2.29
75-79	1	1.02	0.98	2	1.58	1.27	2	2.26	0.89 0.10,3.20
80-84	0	0.56	-	0	0.70	-	3	1.11	2.71
85+	0	0.15	-	0	0.11	-	1	0.15	6.60
Overall	4	4.44	0.90 0.24,2.23	9	7.22	1.25 0.57,2.35	15	10.26	1.46 0.82,2.41

*ICD-8, International Classification of Diseases, Eighth Revision.

+Based on rates for U.S. white males, adjusted for age and calendar year.

++Fisher's exact confidence limits.

-Less than two deaths expected.

number of observed deaths for digestive cancers in the hourly male retired group was less than expected for Y-12 (SMR = 0.91). The deficit finding, however, was not statistically significant.

The number of deaths from cancer of the prostate was slightly elevated for ORGDP (SMR = 1.25) and Y-12 (SMR = 1.46) retired hourly males. In the ORNL male population the number of prostatic cancers was lower than expected (SMR = 0.90). However, this type of cancer death never reached statistical significance in any of the hourly male cohorts at the three plant sites. Notwithstanding the relative importance of these findings, the etiology of prostatic cancer remains essentially unknown. There are no indications from these data that occupational exposures were responsible for the slight excess of these cancers. On the other hand, lifestyle factors may have had a more clear association with prostatic cancer risk in the hourly male cohort. Certain factors (i.e., sexual behavior and dietary habits) associated with lifestyle can be implicated as causal risk factors for prostatic cancer.

In general, married men have a slightly higher risk for prostate cancer than single men. The possible relationship with various sexual factors (i.e., some sexually transmitted viruses) has been investigated in a number of studies (Rotkin, 1979; Mandel and Schuman, 1980; Mishina, et al., 1981; and Ross, et al., 1983). In these studies, there is little evidence offered to link male sexual behavior to an increase in prostatic carcinogenesis.

The epidemiology of prostatic cancer has implicated dietary factors as possibly a more plausible explanation for the disease (Winkelstein, 1979; Piscator, 1981; and Greenwald, 1982). In these studies dietary fat consumption is more consistently and strongly associated with prostatic cancer than either environmental factors (i.e., occupational exposures) or sexual activity. Because of the ages of this study cohort and the region of the country in which the members of the cohort worked, it is suspect that their diets were high in fat content.

Therefore, it is concluded that socioeconomic status did not influence death rates for prostatic cancers in the male study population.

The overall number of observed deaths from lung cancers was significantly elevated in the retired hourly males of ORGDP (O/E = 43/26.92; SMR = 1.60) and Y-12 (O/E = 59/37.88; SMR = 1.56). The overall number of lung cancer deaths was nonsignificantly elevated in the ORNL retired male population (O/E = 21/15.12; SMR = 1.39).

The pattern of increased lung cancer in the U.S. is largely attributed to increased smoking among Americans from the 1930s to the 1960s (Smith, 1987). Cigarette smoking is the single factor responsible for the most preventable type of death in American society (Health-United States, 1988). The largest number of excess deaths among cigarette smokers is due to lung cancers and, to a lesser extent, chronic obstructive lung disease and coronary heart disease. Cigarette smoking also increases the risk of mortality from cancer of certain organs of the digestive system (e.g., bladder, pancreas, and kidney).

Smoking also increases the risk of cancer of the larynx and other cardiovascular diseases. It has been well documented that the risk of mortality among smokers increases with the amount smoked, the duration of smoking, and the tar and nicotine content of the tobacco product (Castelli, et al., 1981; Correa, et al., 1983; Doll and Hill, 1952; Fisher, 1959; Wald and Doll, 1983; and Wald, et al., 1983). Moreover, the risk of death is greater among smokers who began smoking at a younger age than it is among those who began later in life.

Tobacco and tobacco smoke contain many distinct classes of chemical carcinogens and co-carcinogens. The polynuclear aromatic hydrocarbon (PAH) fraction of tobacco smoke is a principal contributor to the active carcinogenic activity in smoke. N-nitrosamines are a second major class of carcinogen found in tobacco and tobacco smoke. These chemical carcinogens are usually found in lung cancer cases that occur in the bronchial tree of the

lungs or in the tissue of either lung. A prime example is squamous cell carcinoma (more frequent in men than in women) which involves the flat, scaly cells of the bronchial epithelium. This form of cancer accounts for 35% to 50% of all lung cancers and has been linked to smoking (Smith, 1987).

With lung cancer, as with other cancers, timely diagnosis of the disease is vital. Typically, the disease is already extensive when diagnosed (75% are technically unresectable) and, therefore, the prognosis is poor. Smith (1987) suggests that most patients die from either dissemination of disease or infection. These findings partly support Hanis' (1985) postulation that any HWE probably occurs in younger populations with fewer years of employment and may not act on site-specific cancer mortality rates (Hanis, et al., 1985).

Heavy tobacco use can be incriminated as a major contributor to the significant number of excess lung cancer deaths in the ORGDP and Y-12 hourly populations. The elevated findings are also augmented by a statistically significant increase in overall death rates for ORGDP ($O/E = 45/28.20$, $SMR = 1.60$) and Y-12 ($O/E = 59/39.63$, $SMR = 1.49$) for all malignant neoplasms of the respiratory system. This finding further implicates smoking as a key cause of lung cancer in these two hourly populations (see Table 24). However, the lack of elevated death rates from all nonmalignant respiratory diseases in the hourly populations of ORGDP ($O/E = 29/26.68$, $SMR = 1.09$) and Y-12 ($O/E = 37/37.03$, $SMR = 0.99$) made it difficult to corroborate smoking as the single key causal factor in the significant excess number of lung cancer deaths. Also, the unavailability of data on cigarette smoking in this study population limited the interpretation of the lung cancer findings. The overall number of deaths from malignant and nonmalignant respiratory diseases is shown in Table 24.

Several studies have purported that cancer of the lung is elevated among nuclear industry workers (Gilbert, 1988; Checkoway, et al., 1988; and Cragle, et al., 1988). This is principally because the lung has been identified as the primary target organ for certain airborne radiological and chemical compounds.

The delayed effects of exposure to ionizing radiation or noxious chemicals have been shown in numerous occupational studies to be associated with various cancers and diseases of the respiratory system. However, two studies of Oak Ridge workers have suggested that such exposures were not sufficient to cause mortality that would significantly differ from the U.S. population. The first of these is a mortality study (Polednak and Frome, 1981) of 18,869 white males employed between 1943 and 1947 in a uranium processing facility at the Y-12 Plant. The authors hypothesized that lung cancer and leukemia would be among the cancer types to be related to exposures to uranium. Generally, mortality among the cohort was found not to be significantly different from the U.S. population for both lung cancer and leukemia. They also found that SMRs among workers employed in areas suspected to have the highest potential for uranium exposure were not extraordinary. These analyses did not, however, consider exposures to other chemical agents.

The second study (Checkoway, et al., 1985) examined mortality among 8,375 white males employed between 1943 and 1972 at ORNL. Using the U.S. population as a standard for comparison, SMRs were used to investigate dose-response among the cohort for all causes, all cancers, leukemia, and cancers of the prostate. Findings suggest that a nonsignificant dose-response may be associated with leukemia at 10 years induction. The other causes of death examined showed no such association. SMRs were 1.00 for the unexposed, 1.38 for the 0.001-0.999 rem exposure category, and 2.70 for the 1.000-4.999 rem exposure category. No cases were observed among persons receiving ≥ 5 rems of exposure.

Although these studies have shown that little, if any, positive associations exist between occupational exposures and mortality outcome in the active DOE-Oak Ridge workforce, one cannot entirely dismiss the notion that some proportion of the death rates from the hourly male retirees may be indirectly linked to some risk factor or a combination of risk factors that is associated with one's workplace. It has been suggested that less-than-healthy workers were not screened out of the initial workforce of the Oak Ridge government facilities because of the war (WWII) effort. Of those individuals it was believed that many of the blue collar employees in the war era were considered to have no formalized education (Frome, 1990). Moreover, it was suspected that during the war years, industrial hygiene and health physics standards of the facilities at Oak Ridge, as well as at other government facilities throughout the country, were not as stringently regulated and aggressively enforced as they are today (Dupree, et al., 1987 and Cragle, et al., 1988). If there were toxic materials in the workplace and standards governing their storage and usage were lax, exposure potential was high, and such exposure could potentially create devastating health consequences over a protracted period of time.

Because of the carry-over in the HWE, it was unexpected to find the all causes SMR significantly elevated in the retired ORGDP and Y-12 cohorts for the age-bands 50-64. Even more unexpected was the significantly elevated finding for circulatory diseases in the ORGDP group for age-bands 50-64. Perhaps the long follow-up period (34 years) nullified the carry-over in health status for this group. There is no clear explanation for the significant elevation in circulatory disease SMR values. Conversely, several possible reasons for the statistically significant elevations in cancer deaths for the retired populations of ORGDP and Y-12 have been provided. Although the potential for exposure to ionizing radiation from various sources (e.g., cesium, cobalt, strontium, and primarily uranium) was more likely for blue collar

employees than for salaried employees in this study no biological plausability of an association between radiation exposure and mortality gradients from all or specific causes can be implicated.

It has also been suggested that exposure to ionizing radiation may cause cancer in several target organs (e.g., lung, bone, and thyroid) due to inhalation or ingestion of radioactive compounds (BEIR V, 1990). While the mechanism of radiation-induced diseases remains somewhat obscure, some researchers have suggested that prolonged chemical exposures are more likely than radioactive substances to cause excess cancer mortality (Hueper, 1966; Plunkett, 1977; and Soskolne, et al., 1984). The association between cancer deaths and presumed chemical exposures has been reported in other occupational studies (Ott, et al., 1978 and Arp, et al., 1983). This researcher's findings of significant increases in the number of cancer deaths in the blue collar populations of ORGDP and Y-12 warrants further investigation, given the nature of the potential for chemical exposures at these Oak Ridge facilities. Also, these findings suggest that the HWE in the blue collar male retired group did not continue to operate in retirement for this group.

Since the use of the general population as a standard has been the subject of criticism in creating the HWE, direct comparison of the blue collar group was made using the salaried group from the total cohort as a standard. The rationale for the use of an alternative standard population was to demonstrate how the use of a different comparison population may yield different interpretations in the results. This method indicated that greater elevated variation between age-specific SMRs and the categories of all causes and all cancers existed. However, it was not surprising to find the highly positive skewed mortality distribution in the lower age-bands.

Because the retired Y-12 population was much larger than either of the other groups, results of the combined analyses were similar to those for Y-12 alone. The combined analyses included the pooled analysis by using the general population as a standard. Nevertheless, none of these elevations were consistently high enough to warrant conclusions that any particular exposure was responsible for the increased mortality risk. The results of the blue collar analysis, therefore, merely allow for speculation.

This portion of the investigation analyzed and discussed some considerations associated with possible carry-over in the HWE in a retired white male cohort. These considerations included sample sizes, socioeconomic status characteristics of stress, age at retirement, age at death, and length of latency for specific diseases. Thus far this study has discovered that the investigation of retirees may serve as an useful barometer in detecting certain occupational hazards and diseases. However, as stated at the outset of this discussion, the study of retirees has its limitations. Because of these limitations, extreme caution must be utilized in generalizing results, especially those with negative outcomes.

It is difficult to interpret the findings of the male analyses due to the fact that reasons for differing mortality patterns in retirees is unclear because congruent analyses have rarely been reported (Carpenter, 1990). This investigation has provided further evidence that socioeconomic status generally influences the carry-over in the HWE for a given retired population. In other words, the HWE does not apply equally to all groups within a given study population. There is, however, little evidence to directly compare the data reported here with results from previous studies of retired persons (which were commonly used reference points) because relevant analyses from such studies are still relatively few (Carpenter, 1990). Future analysis of mortality within the DOE-Oak Ridge retired male

population should consider the impact on longevity of the combined effects of stress, lifestyle behaviors, radiation, and chemical exposures in a retiree's post-retirement years.

Female Cohort Analyses

This portion of the study investigated the mortality experience of white salaried and white hourly females who retired from ORNL, ORGDP, or Y-12 between the years 1960 and 1979. Typically, inclusion of females into mortality studies creates problems with the follow-up of those females. One reason females are difficult to follow-up is because of their customary name change as a result of marriage. Moreover, females are likely to terminate employment after a short period of working to raise a family or to move with a spouse who has been transferred to a different geographic location (Wen, et al., 1983).

The eligibility criteria to enter this study, however, greatly reduced the problems historically associated with female follow-up (see Chapter I for eligibility criteria). Out of the 4,444 retirees included in this study, 387, or 7%, were females (310 salaried and 77 hourly). Of the total number of females, 314 (81%) were alive at the end of the study period. Death certificates were located for all (N = 72) but one of the decedents. The follow-up was successful for 99% (three lost to follow-up) of the females.

In this type of study there is always a delusionary effect risk, whereby significant findings within certain subgroups may be overlooked because of small sample size. As such, the analysis of a small number of person-years would result in considerable loss of estimating precision in the female population. Because of this, comparisons of the mortality experience of the female retirees at individual plant sites to that of the U.S. population were not performed. To further increase the statistical power of the female analysis, 5-year age intervals were compressed into 10-year intervals to increase the number of person-years for

a given age-range. There was a total of 4,338.88 person-years (3,383.40 salaried plus 955.48 hourly) observed in the female cohort.

Age-Specific SMR Analyses of the Pooled Salaried Female Cohort and Hypotheses Outcomes

The pooled salaried female group contained 310 retirees, of which 56 were dead. Death certificates were retrieved for 55 (98%) of these observed deaths, and three (0.5%) persons were lost to follow-up. SMR analysis of causes of death was confined to all cancers (16 observed) and diseases of the circulatory system (23 observed), since they comprised 70% of the all causes category in the salaried female cohort. Table 27 shows the age-specific SMRs for all and selected causes. Table 28 provides the number of person-years of observation by 10-year age-bands for the salaried females. Person-years in each 10-year age-band were distributed in a time-dependent manner. As a result, a retiree in the 70-79 age-band contributed person-years to the two categories through which she passed until she was eligible to enter the 70-79 age-band.

As shown in Table 27 the number of deaths due to all causes in the pooled salaried female group for age-band 50-59 (95% C.I. = 0.69, 3.50) was slightly elevated (SMR = 1.72). However, the wide confidence limits reflect the numerical instability of this estimate.

It was not altogether surprising to find deficit mortality (SMR = 0.65) for all causes in the age-band 60-69 (95% C.I. = 0.39, 1.03) because of carry-over in the HWE. This finding was inconsistent with the significantly elevated mortality seen for all causes in the pooled salaried age-group 60-69. Mortality rates were as expected for all causes in the age-band 70-79 (95% C.I. = 0.68, 1.49). This finding provided evidence retirees aged. Mortality rates contained a deficit SMR (0.62) in the all causes category for the age-band

TABLE 27

Standardized Mortality Ratios (SMR) for All and Selected Causes of Death by Ten-Year Age Bands for the Combined Female Salaried Population

	All Causes			All Cancers			Circulatory Diseases		
	O / E ⁺	SMR	95% C.I. ⁺⁺	O / E ⁺	SMR	95% C.I. ⁺⁺	O / E ⁺	SMR	95% C.I. ⁺⁺
50-59	7	4.07	1.72	4	1.63	2.45	1	1.38	0.72
60-69	18	27.62	0.65	6	8.88	0.68	6	12.59	0.48
70-79	27	26.34	1.03	6	6.10	0.98	12	14.88	0.81
80+	4	6.47	0.62	0	0.90	0	4	4.25	0.94
Overall	56	64.50	0.87	16	17.51	0.91	23	33.10	0.70

*ICD-8, International Classification of Diseases, Eighth Revision.

⁺Based on rates for U.S. white females, adjusted for age and calendar year.

⁺⁺Fisher's exact confidence limits.

⁺⁺Statistically significant (P<0.05).

TABLE 28

Basic Characteristics of the Study Populations of Retired White Females from the ORNL, the ORGDP, and the Y-12 Plant.

	ORNL	ORGDP	Y-12	Totals
Number of Retirees				
Salaried	119	143	125	387
Hourly	115	125	70	310
Person-Years (combined)	4	18	55	77
Salaried	1,380.9	1,712.33	1,245.66	4,338.88
Hourly	1,316.22	1,371.16	696.02	3,383.40
Average Follow-Up	64.67	341.17	549.64	955.48
Salaried	12 years	12 years	10 years	11 years
Hourly	12 years	11 years	10 years	11 years
Number Alive	16 years	19 years	10 years	12 years
Salaried	101	108	102	311
Hourly	99	96	56	251
Number Dead	2	12	46	60
Salaried	17	34	22	73
Hourly	15	28	13	56
Unknown Vital Status	2	6	9	17
(All Salaried)	1	1	1	3

80 and older (95% C.I. = 0.17, 1.53). Since this finding was based on four observed deaths versus 6.47 expected, caution is advised in its interpretation.

The all cancers category showed mortality to be nonsignificantly elevated (SMR = 2.45) in the age-band 50-59 (95% C.I. = 0.66, 6.05). Here again, the wide confidence interval indicate that this estimate was numerically unstable. Moreover, the finding was based on four observed deaths and 1.63 expected deaths. The number of deaths in the proceeding age-bands 60-69 (95% C.I. = 0.25, 1.45) and 70-79 (95% C.I. = 0.36, 2.11) had mortality rates lower than those of the general population. However, because the number of observed deaths in these all cancer age-bands (six deaths in both groups) were so few, reliable speculation of the results would be questionable at best. There were no cancer deaths observed in the 80 and older age-band.

Table 29 provides a summary by facility of the number and types of cancers found in the pooled female salaried group. Although no in-depth analysis and subsequent discussion was done from Table 30, the data is offered to demonstrate how small sample size may cause SMRs to look excessively high when, in fact, in this study they were predominately based on expected values less than 1.00.

Mortality was less than expected for circulatory diseases in all age-bands. Upper confidence limits based on the pooled salaried female group's data for circulatory diseases were roughly comparable to those of the pooled salaried male group. The confidence limits in the female population were based on small numbers of deaths in age-bands 50-59 (O/E = 1/1.38), 60-69 (O/E = 6/12.59), 70-79 (O/E = 12/14.88), and 80 and older (O/E = 4/4.25). None of these differences achieved statistical significance.

In general, no consistent associations emerged from the results of SMR analyses for all causes, all cancers, or circulatory diseases according to retirement age in the pooled

TABLE 29

Number and Category of Specific Cancer Sites in the Salaried Populations of ORNL, ORGDP, and the Y-12 Plant by 10-Year Age Bands, 1960-1979.

Cancer Category									
Age (years)	Digestive Organs	Lung	Bone	Breast	All Genital	Kidney	Brain & CNS	All Cancers	
ORNL									
50-59	0	0	0	0	0	0	0	0	
60-69	1	0	0	0	1	0	0	2	
70-79	0	0	0	0	0	0	0	0	
80+	0	0	0	0	0	0	0	0	
Overall	1	0	0	0	1	0	0	2	
ORGDP									
50-59	0	0	0	1	1	0	0	2	
60-69	1	0	1	0	2	0	0	4	
70-79	1	0	0	2	1	1	0	5	
80+	0	0	0	0	0	0	0	0	
Overall	2	0	1	3	4	1	0	11	
Y-12									
50-59	0	0	0	1	0	0	1	2	
60-69	0	0	0	0	0	0	0	0	
70-79	0	1	0	0	0	0	0	1	
80+	0	0	0	0	0	0	0	0	
Overall	0	1	0	1	0	0	1	3	
Total	3	1	1	4	5	1	1	16	

TABLE 30

SMRs for All and Specific Causes of Death Observed in the Combined Salaried Female Cohort: 1960-1979

ICD 8	Category	Observed	Expected	SMR
000-998	All Causes	56	64.50	0.87
140-209	All Cancers	16	17.51	0.91
250	Diabetes	2	1.12	1.79
263	Vitamin B Deficiency	1	0.89	1.12
348	Motor Neurone Diseases	1	0.30	3.33
390-458	Diseases of the Circulatory System	23	33.10	0.70
460-519	Nonmalignant Diseases of the Respiratory System	4	2.07	1.93
520-577	Nonmalignant Diseases of the Digestive System	2	1.73	1.16
780-799	Ill-Defined Conditions	4	0.55	7.27
-	Unknown	3	-	-

salaried female population. The most notable overall finding from the salaried female cohort analysis was that mortality rates for most causes of death were lower than those of the U.S. population. Deficits in mortality from all causes and for the two specific causes investigated were commonly attributed to the HWE (Cragle, et al., 1988).

These findings support acceptance of the replicated null hypothesis-3 (there will be no differences in survivorship and mortality experience for the combined salaried female populations from ORNL, ORGDP, and Y-12 when compared to the U.S. for all causes, all cancers, diabetes, all respiratory diseases, diseases of the digestive system, cirrhosis of the liver, genito-urinary diseases, accidents, and suicide). Replicated alternative hypothesis-3 was rejected (excess in the death rates will be seen for the combined salaried female populations of ORNL, ORGDP, and Y-12 when compared to the U.S. for all circulatory diseases (i.e., cardiovascular and cerebrovascular diseases combined).

Age-Specific SMR Analyses of the Pooled Hourly Female Cohort and Hypotheses Outcomes

The pooled hourly female group contained 77 retirees, of which 17 were dead. Death certificates were retrieved for all (100%) observed deaths, and no persons were lost to follow-up. Although the results were based on a combined three-plant hourly female retired population (4338.89 person-years observed for the total female cohort, of which 955.48 person-years were for the hourly female group), the reliability of these analyses is questionable because of the small number of cases involved (see Table 28). Therefore, the hourly female group is not a reasonable representation of what one would expect in a comparable segment of the U.S. population.

SMR analyses of causes of death were confined to all cancers (5.00 observed) and diseases of the circulatory system (7.00 observed), since they comprised 71% of the all

causes category in the hourly female population. Table 31 lists in 10-year age-bands the number of observed deaths for various causes within the hourly female group. For the middle age-bands, 60-69 and 70-79, the number of observed deaths and person-years was large enough for estimating death rates with acceptable reliability. However, there were substantially fewer observed deaths and person-years of observation in the 50-59 age-band and in the 80 and older age category. These differences reflect that blue collar women in post-retirement died at a lower rate than their male blue collar counterparts.

As shown in Table 31, the number of deaths due to all causes in age-band 50-59 (SMR = 1.44) was nonsignificantly elevated. The elevation was attributed to 1.00 observed cancer death (versus 0.70 expected deaths). The number of observed deaths for all causes in the succeeding age-bands 60-69 (SMR = 0.90), 70-79 (SMR = 0.76), and 80 and older (SMR = 0.35) exhibited mortality rates less than expected, but the differences were not statistically significant.

In the all cancers category, 5.00 deaths occurred among the hourly female group. Although the number of deaths was small, the mortality pattern of the hourly females was generally better than that of the hourly males. The SMRs for all cancers varied between 3.85 and 0.83 for different age-bands, with an overall SMR of 0.93 for blue collar females aged 50 to 80, and older. There were no statistically significant elevations or decrements in any age-band for the pooled hourly female group. Here again, the number of cases was too small to enable detection of any meaningful trends.

Table 32 provides a summary by facility of the number and types of cancers found in the pooled female hourly group. Although no indepth analysis and subsequent discussion is provided relative to Table 33, the data is offered to demonstrate how small sample size may

TABLE 31

Standardized Mortality Ratios (SMR) for All and Selected Causes of Death by Ten-Year Age Bands for the Combined Female Hourly Population

	All Causes			All Cancers			Circulatory Diseases					
	O / E*	SMR	95% C.I.**	O / E*	SMR	95% C.I.**	O / E*	SMR	95% C.I.**			
50-59	1	0.70	1.44	- , -	1	0.26	3.85	0	0.26	0	- , -	
60-69	7	7.81	0.90	0.36,1.83	2	2.41	0.83	0.16,2.23	3	3.68	0.82	0.16,2.23
70-79	8	10.54	0.76	0.36,1.48	2	2.39	0.84	0.18,1.64	4	6.02	0.67	0.18,1.64
80+	1	3.28	0.35	- , -	0	0.31	0	- , -	0	1.50	0	- , -
Overall	17	22.33	0.76	0.44,1.22	5	5.37	0.93	0.30,2.13	7	11.46	0.61	0.25,1.24

*ICD-8, International Classification of Diseases, Eighth Revision.

*Based on rates for U.S. white females, adjusted for age and calendar year.

**Fisher's exact confidence limits.

**Statistically significant ($P < 0.05$).

-Less than two deaths observed.

TABLE 32

Number and Category of Specific Cancer Sites in the Hourly Female Populations of ORNL, ORGDP, and the Y-12 Plant by 10-Year Age Bands, 1960-1979.

Cancer Category					
Age (years)	Digestive Organs	Bone	Breast	Brain & CNS	All Cancers
ORNL					
50-59	0	0	0	0	0
60-69	0	0	0	0	0
70-79	0	0	0	0	0
80+	0	0	0	0	0
Overall	0	0	0	0	0
ORGDP					
50-59	0	0	0	0	0
60-69	0	0	0	0	0
70-79	0	0	1	1	1
80+	0	0	0	0	0
Overall	0	0	1	1	1
Y-12					
50-59	0	0	1	0	1
60-69	0	1	0	0	2
70-79	1	0	0	0	1
80+	0	0	0	0	0
Overall	1	1	1	0	4
Total	1	1	2	1	5

TABLE 33

SMRs for All and Specific Causes of Death Observed in the Combined Salaried Female Cohort: 1960-1979

ICD 8	Category	Observed	Expected	SMR
000-998	All Causes	17	22.33	0.76
140-209	All Cancers	5	5.37	0.93
230	Neoplasm of Unspecified Nature of Digestive Organs	1	0.03	33.33
250	Diabetes	1	0.24	4.17
290	Mental Disorder (Senility)	1	0.00	-
483	Pneumonia	1	0.43	2.33
795	Sudden Death (unknown)	1	0.10	10.00

cause SMRs to look excessively high when, in fact, in this study they were predominately based on expected values less than 1.00.

The overall number of deaths due to circulatory diseases (SMR = 0.61) was lower ($p < .05$) than expected. The number of observed deaths by 10-year age-bands 60-69 (SMR = 0.82) and 70-79 (SMR = 0.67) was also less than expected, but none of the decrements were statistically significant. There were no deaths observed in the 50-59 and 80 and older age-bands. The mortality ratios for the hourly female population were not congruent to those of the hourly male population, but were very similar to those of the salaried female population. In the female hourly population, there were only two instances in which SMRs for investigated causes of death were greater than 1.00. These slightly elevated SMRs could be of biological importance even though they were not statistically significant. In general, the mortality from all causes, all cancers, and circulatory diseases in the hourly female population compared favorably to that of the U.S. population.

Replicated null hypothesis-4 (there will be no differences in survivorship and mortality experience for the combined hourly female populations from ORNL, ORGDP, and Y-12 when compared to the U.S. for diabetes, all respiratory diseases, cirrhosis of the liver, genitor-urinary diseases, accidents, and suicide) was accepted. However, replicated alternative hypothesis-4 (excess in the death rates will be seen for the combined hourly populations of ORNL, ORGDP, and Y-12 when compared to the U.S. for all causes, all cancers, circulatory diseases [i.e., cardiovascular and cerebrovascular diseases combined], and diseases of the digestive system) was rejected.

**Analyses of the Direct Comparison of the Standardized
Female Pooled White Collar Population to the Female
Pooled Blue Collar Population and Hypotheses Outcomes**

As in the two previous phases of the female analyses, mortality outcomes in this phase were investigated for all and selected causes of death within a single combined hourly population. Once again, the major reason for combining data from different DOE plants was to increase precision of risk estimates. The principal difference between this female analysis and the previous female analyses is that pooled salaried females were used as the standard population for comparison. This analysis was limited to the investigation of all causes, all cancers, and diseases of the circulatory system since they comprised the vast majority of deaths in both the hourly and salaried population. The following age-band standardization formula was used to convert the salaried female population to a standard group:

$$\begin{aligned}
 \text{Age-Band} &= \frac{\text{Observed White Collar}}{\text{Person-Years White Collar}} \times \text{Person-Years Blue Collar} \\
 &= \text{Expected Blue Collar (based on white collar)} \\
 &= \frac{\text{Observed Blue Collar}}{\text{Expected Blue Collar}} \\
 &= \text{SMR}
 \end{aligned}$$

Table 34 shows the cause-specific SMRs for the pooled hourly female population relative to the standardized salaried female population for the years 1960 through 1984. The overall SMR (1.08) for all causes in the pooled hourly female population was slightly elevated (95% C.I. = 0.63, 1.72). For the all causes category age-specific SMRs were somewhat sporadic over every age-band. The ratios for all causes varied between 0.77 and 2.86 for the different age-bands; however, no SMR differed significantly from unity. No strong upward or downward trend was apparent.

TABLE 34

Standardized Mortality Ratios (SMR) for All and Selected Causes of Death by 10-Year Age Bands for Combined Hourly Female Population When Directly Compared to a Standardized Salaried Female Population.

	All Causes			All Cancers			Circulatory Diseases					
	O / E ⁺	SMR	95% C.I. ++	O / E	SMR	95% C.I. ++	O / E ⁺	SMR	95% C.I. ++			
50-59	1	1.12	0.89	- , -	1	0.64	1.56	- , -	0	0.16	0	- , -
60-69	7	4.87	1.44	0.58,2.93	2	1.62	1.24	0.14,3.76	3	1.62	1.85	0.37,5.07
70-79	8	10.45	0.77	0.33,1.50	2	2.32	0.86	0.10,2.62	4	4.65	0.86	0.23,2.13
80+	1	0.35	2.86	- , -	0	0	0	- , -	0	1.38	0	- , -
Overall	17	15.82	1.08	0.63,1.72	5	4.52	1.11	0.36,2.53	7	6.50	1.08	0.43,2.19

*ICD-8, International Classification of Diseases, Eighth Revision.

⁺Based on rates for U.S. white females, adjusted for age and calendar year.

++Fisher's exact confidence limits.

-Less than two deaths expected.

There was no evidence of mortality gradients for all cancers or for diseases of the circulatory system in the pooled hourly female population when it was compared to the standardized group. The ratios of age-specific mortality rates for 5-year age-bands tend to varied over a smaller range than in the all causes category, but the vast majority of ratios were greater than 1.00. These ratios had wide confidence limits and, thus, less precision than those derived from the all causes category. There were too few deaths from all cancers ($O/E = 5/4.52$) and circulatory diseases ($O/E = 7/6.50$) to warrant a more detailed analysis of these numerically unstable estimates. Therefore, for the female retirees the small number of deaths from all cancers and circulatory diseases in both the pooled hourly female group and the pooled salaried female group precludes inferring that the risks of these diseases were greater for one group than for another.

Replicated null hypothesis-5 (there will be no differences in survivorship and mortality experience for the combined hourly female populations from ORNL, ORGDP, and Y-12 when compared to a standardized white collar population from the same facilities for diabetes, all respiratory diseases, cirrhosis of the liver, genito-urinary diseases, accidents, and suicide) was rejected.

The rejection of replicated alternative hypothesis-5 (excess in the death rate will be seen for the combined hourly populations of ORNL, ORGDP, and Y-12 when compared to a standardized white collar population from the same facilities for all causes, all cancers, circulatory diseases [i.e., cardiovascular and cerebrovascular diseases combined], and diseases of the digestive system) is consistent with the previous female findings in this study; that is, socioeconomic status has no apparent influence on death rates in the female study cohort.

General Discussion

The results of this portion of the investigation indicate that the overall mortality experience of retired females, regardless of socioeconomic status, from the DOE-Oak Ridge facilities was better than or consistent to that of the total U.S. population for all causes of death, all cancers, and circulatory diseases. This finding is probably attributed to a carry-over in superior health status enjoyed during the retirees' employment years. It would appear that the traditional jobs held by women in an occupational setting has had a profoundly beneficial, though largely unplanned impact on the general health status of this population during its post-retirement years.

Female salaried jobs are fewer in number than male salaried jobs and are concentrated in lower-middle-class levels, primarily weekly white collar positions (e.g., secretary, records clerk, or laboratory technician). These types of jobs are normally non-strenuous and, more importantly, are typically located away from radiation and chemical hazards that have long latency periods.

Conversely, women who choose a blue collar occupation are concentrated in the unskilled or semi-skilled positions (e.g., cafeteria worker, janitor, or laborer). Masculine jobs in the blue collar ranks traditionally were associated with skilled crafts (e.g., pipefitter, electrician, or machinist). In other words, androgynous positions are few and far between in the hourly workforce. This finding is reflective of the relatively small number of blue collar women who retired from the facilities under investigation. Surprisingly, both white and blue collar female work patterns did not radically changed over the time period being investigated. This appears to be a major reason for the better than average longevity rate displayed in the female study group when it was compared to the average longevity rate of the U.S. population.

Within the total study population, the male-female survival rates tended to become more diverse with age. Even though minor significant increases or decreases were found in the mortality rates of the male cohort, there was no mortality rate significance found in the female group due to its small size. For example, there was an overall deficit in the number of deaths from all causes, all cancers, and all circulatory diseases in both the white and blue collar female groups when compared to the U.S. population. Some researchers may suggest that such deficits are a direct result of the small sample size in the female population (Collins and Redmond, 1978).

Another possible explanation for the deficit findings in the female groups could be that women were excluded during their working years from various jobs or workplaces that were suspected of posing greater toxicological risk to female reproductive capability. Women were probably excluded from certain jobs because significant doses of radiation are known to cause miscarriage, infertility, and even birth defects (Levy, et al., 1984). Additionally, females were more than likely kept away from jobs involving chemicals because, when compared to the effects of radiation, the effects of exposure to complex chemical products create an equally hazardous risk to female sex organs (Messite and Bond, 1980).

The aforementioned findings notwithstanding, it is believed that the practice of excluding women from certain jobs during the early years (1940s to mid-1960s) of DOE-Oak Ridge operations was caused more by masculine labor force behavior than by a true concern for female health. An exclusionary policy based on sex for particular jobs generally was accepted throughout the country (Van Horn, 1989). It was not until the 1960s that serious consideration was given to the exclusion of females from various workplaces because of toxicological hazardous (Messite and Bond, 1980). Although no hard evidence was found to support the assumption, the retired Oak Ridge female population being studied did appear

to fall within this exclusionary trend. Nevertheless, the person-years data shown in Table 28 seems to support Van Horn's exclusionary theory.

For example, the hourly populations of ORNL and ORGDP contained only 405.84 person-years, as compared to 2,687.38 person-years in the female salaried populations from the same two sites. Such small numbers imply that hourly females were more frequently excluded from employment than their salaried counterparts at ORNL and ORGDP. The Y-12 population showed little difference in the general makeup of hourly (549.64 person-years) and salaried (696.02 person-years) females. This makeup was probably due to Y-12 employing predominately blue-collar personnel. Even so, the small overall number of person-years (1,245.66) in the Y-12 group signify that females were excluded from certain jobs. The small number of females (387) in this cohort more than likely was essentially attributed to the exclusion of women from androgynous positions within the three-plant workforce.

Female exclusion from exposure to hazardous work processes within the DOE-Oak Ridge plant sites appears to have beneficially impacted female death rates. Tables 35 and 36 provide further evidence that female retirees from the Oak Ridge facilities had a higher survivor effect than a comparable segment of the U.S. population. The higher survivor rate also contributed to the mostly low SMRs that were observed in the female population.

Lifestyle factors provided another plausible explanation as to why overall death rates were so unexpectedly low among both the white and blue collar female groups. Two commonly-used socioeconomic predictors of mortality outcome in lifestyle behaviors are tobacco usage and alcohol consumption. It is believed, however, since such behaviors for women were more socially unacceptable during the early years of Oak Ridge operations (1940s to mid-1960s), that these health-status risk characteristics were readily adopted by the

TABLE 35

Number of Days Lived Following Retirement in the Female Salaried Population by 10-year Age Bands for ORNL, ORGDP, and the Y-12 Plant.

Age	Survival Time (Days)							Total	
	60-89	90-179	180-299	300-729	730-1459	1460-1824	≥ 1825	Dead	
ORNL									
50-54	0	0	0	1	0	0	0	1	
60-69	0	0	0	0	0	2	1	3	
70-79	0	0	0	0	0	0	9	9	
80+	0	0	0	0	0	0	2	2	
ORGDP									
50-54	0	1	0	2	1	0	0	4	178
60-69	0	0	1	0	3	3	4	11	
70-79	0	0	0	0	0	0	13	13	
80+	0	0	0	0	0	0	0	0	
Y-12									
50-54	0	1	0	1	0	0	0	2	
60-69	0	0	0	0	1	0	3	4	
70-79	0	0	0	0	0	0	5	5	
80+	0	0	0	0	0	0	2	2	
Total									
Dead	0	2	1	4	5	5	39	56	

TABLE 36

Number of Days Lived Following Retirement in the Female Hourly Population by 10-year Age Bands for ORNL, ORGDP, and the Y-12 Plant.

Survival Time (Days)					Total Dead
Age	60-89	730-1459	1460-1824	≥ 1825	
ORNL					
50-54	0	0	0	0	0
60-69	0	0	0	0	0
70-79	0	0	0	5	5
80+	0	0	0	1	1
ORGDP					
50-54	0	0	0	0	0
60-69	0	0	0	2	2
70-79	0	0	0	0	0
80+	0	0	0	0	0
Y-12					
50-54	1	0	0	0	1
60-69	0	1	1	3	5
70-79	0	0	0	3	3
80+	0	0	0	0	0
Total Dead	1	1	1	14	17

average female worker. While there is no data to support the foregoing assumption, the causes of death among the female population tend to suggest that physical-risk lifestyle behaviors are not necessarily one of the better estimators of true mortality risk in such a cohort.

By using the standard mortality ratio as a means of comparison, the mortality experience between two different combined female groups was examined in relationship to socioeconomic status in an attempt to measure the magnitude of carry-over in the HWE. For the most part, overall SMRs for females were impressively low regardless of socioeconomic status, although some variation was observed within the 10-year age-bands. The overall deficits in SMRs were unexpected.

One of the major health concerns of retirees from an industrial setting is the possibility of a latent risk of lung or respiratory disease (Shindell, et al., 1978 and Sterling and Weinkam, 1986). Therefore, one would expect to see a steadily unfavorable mortality experience as a given retiree ages (McMichael, 1976). However, this did not prove to be the case with white or blue collar women. Even those diseases with long latent periods (i.e., breast cancers, genital cancers, and other neoplastic diseases) have been found to be of marginal risk to the female study groups when compared to the U.S. population.

Cancer deaths were distributed over seven organ-specific locations (see Tables 29 and 32). Twenty-nine percent of all deaths in the female population appeared to be caused by malignant neoplasms. The number of observed deaths for all cancers was less than expected for both the white and blue collar females (SMR = 0.91 and 0.93, respectively), but the difference was not statistically significant.

When the female groups were compared to one another, the white collar female mortality experience was only slightly better than that of the blue collar group. Here again,

a possible reason for the positive correlation among the overall female mortality rates may be due to compatibility in lifestyles. It is believed that a large portion of females in this study routinely took extensive medical examinations that probably resulted in the early detection of many chronic diseases. Medical intervention may then have influenced the reduction in age-specific and overall deficits in female death rates more than did the females' socioeconomic status.

The long follow-up period (≥ 34 years) did not nullified the HWE in either the white or blue collar females when compared to the U.S. population. Thus, the female results shed new light on the question of whether or not higher incomes or education levels are associated with lower mortality rates. The results of the female analyses tend to support the hypothesis that, for retired women of the Oak Ridge facilities, socioeconomic status was not directly associated with survival.

CHAPTER V

SUMMARY, MAJOR FINDINGS, CONCLUSIONS, AND RECOMMENDATIONS

This research was undertaken to analyze the nature and extent that the Healthy Worker Effect (HWE) continues to actively operate in post-retirement and to ascertain if, in fact, the HWE is impacted by socioeconomic status. This study has unique importance due to the timeliness of occupational health issues. There is a great deal of interest in this area from the Department of Energy (DOE), and there is a real need for additional knowledge.

Since this is the first singular investigation of retirees, insight derived from this research can provide public health professionals with a solid background to evaluate cause-specific mortality in older persons. The health professionals can then make better employee health decisions either through awareness training or engineered control measures. As a result, significant conclusions and their implications will be discussed in this chapter along with recommendations for future research.

Summary

The analyses described in this study show that several factors are associated with the level of mortality of the DOE-Oak Ridge retired population when it is compared to a similar segment of the U.S. population. The relative contributions of these factors may be divided into three major categories. The first category concerns socioeconomic status and the overall number of deaths observed in the investigated white and blue collar populations. The standardized mortality ratios relative to the retired cohorts' job status (e.g., salaried or

hourly) at retirement are reported in several tables in Chapter IV.

Although the underlying standardized mortality ratios help to explain the significantly high variances displayed in age-specific mortality rates for blue collar male retirees from all causes, all cancers, and circulatory diseases, these findings do not provide a resolution to the question of the impact of socioeconomic status on mortality. Based on findings about the males being studied, it seems reasonable to speculate that higher real income partially explains mortality differences in the male white and blue collar populations. It is surprising, however, to find that socioeconomic status virtually has had no influence on female survival rates in this study. This finding may be the result of no significant differences in real income between white and blue collar females.

In general, the mortality pattern indicates that socioeconomic status has a negative effect for blue collar male retirees, particularly between the ages 50 to 64. For white collar male retirees socioeconomic status has had a positive effect and, for both white and blue collar females, the socioeconomic status of retirees has had a null effect. These generalizations can be made with regard to the male cohort whether or not the white and blue collar analyses are performed by individual plant or by combining plant sites. Small sample size in both the white and blue collar females precludes such broad generalizations.

Nonetheless, these findings should not be too surprising since socioeconomic status has been shown to be linked to the level that one participates in the workforce. The results of this study suggest that people with greater economic means (salaried male employees) in their employment years usually have lower overall mortality rates after retirement. Thus, the level of participation in the workforce could conceivably affect one's survival following retirement.

The second major factor influencing mortality levels of the subjects being studied relates to the general health status of individuals selected for employment at the DOE-Oak Ridge facilities during the World War II era. As suggested in other studies of DOE facilities, the war emergency caused a significant decrease in the number of males whose health status would meet peacetime employment standards. Therefore, many males (predominately blue collar) who had questionable health status were accepted for employment (Dupree, et al., 1987; Cragle, et al., 1988; and Frome, et al., 1990). The postulation that males hired during the World War II era (research of Oak Ridge workers done by Frome, et al. [1990] ascribed this period to be before January 1, 1948) may be less healthy than other male subjects in the study population appears to have some merit. The basis for agreement with Frome's research is evident in the percentage of the total numbers of deaths in the study cohort relative to dates of employment. For example, of the 4,444 subjects that made up the study population, 61.4%, or 2,729 persons, were hired before January 1, 1948. Of that number, 1,117 persons, or 65.9%, are dead. Conversely, the study population was comprised of 38.6%, or 1,715 persons, who were hired on or after January 1, 1948. Of that number, 576 persons, or 34%, are dead. The employment standards did not change for the female group because the war did not markedly affect the available female labor force; however, no data are offered to support this assumption.

One effect of the individual selection factor is suggested by the statistically significant differences observed in standard mortality ratios (SMRs) by socioeconomic status. The highest overall SMRs are seen in the Oak Ridge Gaseous Diffusion Plant (ORGDP) blue collar male population for all causes, all cancers, and circulatory diseases. The overall SMRs

are lowest for all causes and all cancers in the Oak Ridge National Laboratory (ORNL) white collar male retired population. In contrast to this, SMRs are lowest for circulatory diseases within the Y-12 Plant (Y-12) white collar male retired population. Most of the deaths in the Y-12 blue collar male retired population have occurred from circulatory diseases. However, the number of observed deaths is less than expected and includes a larger than average proportion (22%) of decedents from this total blue collar population.

Another possible effect of the selection of unhealthy workers for the initial Oak Ridge workforce could be elevated mortality rates that significantly differ from those of the general U.S. population. In this study analyses based on data for all retirees by pay status indicate that SMRs are highest for the blue collar male group age-bands 50-54 and 55-59 immediately following retirement for the three causes of death investigated (see Tables 14 and 18). However, the salaried males and both the salaried and hourly females did not have the consistently high SMRs over the same age-bands. The blue collar male retirees probably represent a group of individuals who left the workforce because of a chronic illness. This point is strongly presented in Table 21, Part B, in which the data reveals that those individuals retiring early (i.e., before age 62) exhibit death rates significantly higher than the general population. Aside from this logic, there is no clear explanation for the difference in the SMRs.

The third major factor influencing mortality rates in this study is the level of longevity in the total study population relative to sex-age-specific mortality. It has been suggested that, for most species, females outlive males (Comfort, 1979); this study finds no exception. Hence, the evidence presented in this study suggests that two key factors are primarily responsible

for the favorable mortality experience of females. The first factor affecting mortality rates is the initial selection of healthy females into the workforce. The second factor influencing mortality is the exclusion of women from certain hazardous jobs and workplaces that may be associated with diseases having long latent periods. Consequently, these findings suggest that health-related selection and work-related exclusion continue to exert a favorable effect on female death rates in post retirement.

In summary, the evidence presented in this study tends to suggest that occupational, as well as lifestyle, factors may be implicated in the etiology of causes of death investigated. Conversely, several other observations suggest that no association is present. When comparisons are made internally and with the U.S. population, hourly male retirees are observed to have an excess number of deaths from all cancers and, in some age-specific instances, circulatory diseases; but salaried males and all females do not. However, because the total female population is very small, the true risk of occupational susceptibility to diseases may be underestimated.

The analyses of retired males from the Oak Ridge facilities lend support to the postulation that socioeconomic status has a profound effect on death rates. Similar conclusions were reached by Boaz and Muller (1990). They found that mortality is more pronounced in men who worked in physically demanding jobs (i.e., blue collar workers). Further analyses showed that such men tend to be poorer and less educated and tend to have less-than-adequate medical insurance or Medicare coverage in their retirement years. Nonetheless, in the present study the reason for the differential mortality patterns identified is unclear and, since there are few published analyses of similar cohorts, the mortality patterns make the study's results difficult to interpret.

Although it was unexpected to find the all causes SMR significantly elevated in the combined blue collar population (see Table 16), the elevation is probably due to a lack of carry-over in the HWE. The statistically significant excess in the all cancers category contributes the largest component of the significantly elevated all causes SMR. One should also be aware that the significantly elevated mortality experience seen in the blue collar male population is the direct result of death rates being significantly elevated in hourly males who retired before age 62 (see Table 21, Part B).

Because the vast majority of malignant neoplasms in the blue collar male population is associated with cancer of the lungs (see Table 18), heavy tobacco use is suspected as a key contributing risk factor for the statistically significant elevation in death rates from this cause. This suspicion cannot be confirmed because information relative to the cohorts smoking habits was not accessed. In addition, this study did not focus on radiation and chemical hazards in the DOE-Oak Ridge plants, thus a detailed assessment of respiratory cancers was not performed. There is insufficient evidence available at the present time to attribute the significantly elevated death rates in the male blue collar population to any specific occupational or lifestyle factors.

Major Findings

This study has shown that the level of mortality in a retired occupational cohort is likely to depend on the retiree's socioeconomic status, sex, and other health-related characteristics. The mortality rates are low for the investigated causes of deaths among the salaried males and the salaried and hourly females.

Deficits in mortality from all causes combined, all cancers combined, and all circulatory diseases combined are commonly attributed to the HWE (McMichael, 1976). Because many

retired blue collar males engaged in physically demanding jobs during their working careers, it would have been expected that this population would have a reduced risk of mortality for some period of time following retirement as a result of carry-over in the HWE. It was unexpected, however, to find that no effect existed in the male blue collar population when the hypotheses relative to this subgroup were tested. Statistical findings are grouped based on the research questions and corresponding hypotheses presented in Chapter I.

Findings 1 and 2 apply to research question 1; findings 3 and 4 apply to research question 2; and findings 5 to 12 apply to questions 3 and 4. The findings of this investigation are summarized as follows (see Chapter IV, "Hypotheses Outcomes," for complete statements):

1. Overall death rates were essentially the same and, in most cases, lower than expected when compared to the general population for specific causes investigated (null hypothesis-1).
2. The lower-than-expected death rates for all causes, all cancers, and circulatory diseases in the salaried cohort across each facility supports the postulation that the HWE actively continues in following retirement (alternative hypothesis-1).
3. Death rates were slightly different from expected for all causes in the blue collar male subgroups of ORNL and Y-12. It was unexpected, however, to find the all causes category significantly elevated in the ORGDP blue collar male subgroup (null hypothesis-2).
4. There is strong evidence to suggest that the overall mortality risk is significantly increased among those blue collar workers who retired before age 62 from the DOE facilities investigated (alternative hypothesis-2).

5. When the facility-specific cohorts were combined into a single salaried male cohort, there was essentially no difference in death rates and, in most instances, rates were lower than expected when compared to the general population for specific causes of death investigated (null hypothesis-3).
6. Death rates were lower than expected for the specific causes investigated (alternative hypothesis-3).
7. No strong upward or downward trend in mortality was evident in the pooled blue collar male cohort when compared to the U.S. for selected causes (null hypothesis-4).
8. Significantly elevated numbers of death were found in age-specific categories for all causes combined and all cancers combined (alternative hypothesis-4).
9. When the pooled hourly male population was compared directly to the pooled salaried male population for selected causes of death, essentially no differences in mortality were found (null hypothesis-5).
10. The overall number of deaths observed in the pooled hourly male population was found to be significantly elevated for all causes combined, all cancers combined, and all circulatory diseases combined when compared to the pooled salaried male population (alternative hypothesis-5).
11. There were essentially no differences between the mortality experience of the pooled hourly female population and the pooled salaried female population when compared to the U.S. or when compared to each other for selected causes of death (replicated null hypotheses 3, 4, and 5).

12. When compared to the pooled salaried female population, death rates were basically as expected for the pooled hourly female population for all causes combined, all cancers combined, and all circulatory diseases combined (replicated alternative hypotheses 3, 4, and 5).

Conclusions

The analyses conducted to investigate the magnitude of the HWE resulted in the above findings. On the basis of these findings, the following conclusions were drawn:

1. Salaried males who retire at or after age 62 from any of the three DOE-Oak Ridge facilities investigated can generally expect that their mortality rates from all causes will be better than those of the general population (null hypotheses 1 and 3).
2. Salaried males who retire at the normal retirement age (i.e., age 65) will generally live beyond the standard life expectancy (i.e., age 72) for males in the general population (alternative hypotheses 1 and 3).
3. There is a carry-over in the HWE which continues for salaried male retirees at least until the age of 80 years (null hypothesis 1, 3, and 5).
4. Overall, the retired blue collar males at ORGDP and Y-12 appear to be at a significantly elevated risk of mortality from some cancer-specific categories when compared to the general population (alternative hypothesis 5).
5. When taken together (pooled) and compared to the salaried male retired population and to the U.S. population, the overall death rates in the retired blue collar population from all causes are significantly elevated over the expected values. This finding is consistent with the epidemiology literature on

mortality among blue collar workers. Possible explanations for the variations in death rates are given in the previous discussion (null hypotheses 2 and 4 and alternative hypotheses 2 and 4).

6. When the blue collar male population is stratified by age at retirement and by pay status it becomes clearly evident that those individuals who retire before age 62 are at a significantly elevated risk of mortality from all causes combined, all cancers combined, and circulatory diseases combined. Also, the elevated number of deaths in this retired blue collar group (younger than 62 years) is the primary contributor to the significantly elevated mortality findings in the previous analyses of death rates for the total hourly cohort. The data suggest that the elevation of mortality among 50-61 year age groups may be due in part to deaths of workers who retired early because of ill health (null hypothesis 5).
7. Those blue collar males who retire after age 62 are generally expected to live beyond the standard life expectancy (i.e., 72 years) of the general population (alternative hypothesis 5).
8. There is a carry-over in the HWE for those blue collar males who retired at or after age 62. The carry-over is shown to last for a protracted period of time following retirement (i.e., to age 85 and older) (alternative hypotheses 4 and 5).
9. The female cohort, regardless of pay status or age at retirement, essentially has death rates lower than those of the general population. This favorable mortality experience can be attributed to the HWE (null hypotheses 3 and 4).

10. The female retirees, regardless of pay status, basically have lower mortality rates than their male counterparts who retired from the same DOE-Oak Ridge facilities. Possible explanations for these findings include the likelihood that females were not assigned to certain hazardous jobs. Also, the past differentials between male and female smoking habits account for the major proportion of the current differentials in lung cancer mortality among males and females in the general population (replicated alternative hypotheses 3, 4, and 5).
11. When comparison of the female study population is made by pay status (white collar versus blue collar), there are essentially no differences in the mortality experience between these two groups. It is concluded that the exclusionary principal is the key to the similarity in death rates (replicated null hypothesis 5).

Recommendations

Based on the evidence presented in this study, it is recommended that a follow-up of the total study population is needed to evaluate the stability of the HWE relative to its relationship to socioeconomic status. Moreover, this study demonstrates that the small number of person-years in the female population precludes confident deductions regarding this group's favorable overall mortality experience following retirement or its linkage, if any, to occupation. It is recommended, therefore, that continued follow-up of the female cohort is needed to more accurately understand how specific occupations affect a woman's post-retirement mortality risk. Additionally, it is also suggested that continued follow-up of retired

DOE-Oak Ridge workers include minorities. The inclusion of minorities in future studies of the Oak Ridge facilities may provide a more holistic picture of the estimate of true risk from occupational hazards.

In recent studies, researchers have suggested that the etiology of certain occupational diseases may be linked as causal factors to chemical materials, more than to radioactive sources (Waxweiler, 1986 and Dupree, et al., 1987). Hence, it appears that this retiree study may provide clues to occupational hazards from diseases either having a long latency period or diseases requiring long exposure times, or both. A shortcoming of the study, however, is that direct comparison of the data with results from previous studies of DOE facilities is not necessarily valid due to age-specific differences in the cohorts.

This mortality study has provided an illustration of individual and combined analyses of data from three DOE retired worker populations. It is felt that such analyses provide a reliable basis for submitting the evidence on the HWE and how this phenomenon is impacted by socioeconomic status. Based on the findings of this study, it appears that retiree studies could provide a useful means to assist in the detection of some occupational hazards. However, one should be aware of the increased likelihood of spurious negative findings caused by the factors of age, sex, race, and small sample sizes. Also, the findings from a study of retirees will not be directly referencable to the entire population of workers.

The findings of this study also strongly support the hypothesis that a retiree's final job status may significantly influence the carry-over in the HWE following retirement, particularly if that person is an hourly male and retires at or before age 62. The age effect may be associated with poor health status prior to retirement. As such, this study has heavily underscored the need for further research in this important and complex area. Further

follow-up of this cohort should use a study design that will examine the independent and combined effects of potential work-related exposures, such as radiation or chemical, and lifestyle behaviors (e.g., tobacco, alcohol, or substance abuse).

CHAPTER VI

THE STUDY IN RETROSPECT

This retrospective cohort study described the mortality experience of white males and white females who retired from government facilities in Oak Ridge, Tennessee between 1960 and 1979. As demonstrated in the study, mortality patterns do vary among people of different economic class. Moreover, this study has added to the body of knowledge regarding active duration of the healthy worker effect in post retirement.

Social class gradients of mortality and life expectancy have been observed for centuries; this study was no exception. A large body of evidence has consistently shown that those in the lower socioeconomic levels have higher mortality rates. This researcher offered the explanations of lifestyle, poor education, and ability to cope with stress as factors which may directly or indirectly result in such health outcomes as poor nutrition, poor medical care (i.e., not being able to afford health care other than that provided by an employer) and the potential for exposure to noxious agents. While these explanations possibly accounted for some of the observed relationships, this researcher found them not to be totally adequate (in a holistic sense) to explain the large number of observed deaths associated with males from lower socioeconomic status in this study cohort. Nonetheless, the existing evidence on socioeconomic issues implied a positive correlation exists between one's job status and one's longevity.

It should come as no surprise that research of retirees from the DOE-Oak Ridge facilities was heavily supported by Martin Marietta Energy Systems and the DOE. To a large

extent, this may be due to the fact that the elderly population will place a significant medical burden on the remainder of the working population in years to come. Therefore, it is in the best interest of corporate America to try and keep individuals mobile and self-sufficient well into their retirement years. This study provided an initial overview of the state of the health in the retired DOE-Oak Ridge workforce. To the best of this researcher's knowledge, until this investigation no formal information had been compiled on differences between socioeconomic groups and their mortality experience following retirement.

It is believed by the researcher that both Martin Marietta Energy Systems and the DOE have recognized the need for investing in the health education of its young employees. Employees are increasingly being made aware that medical and biological achievements have extended the life span. However, as people age their frequency of disease often increases. Hence, it is important to train young healthy employees how to take a greater individual responsibility for their own health and physical well-being. The magnitude of the impact of such a training effort is expected to reduce the large amount of resources spent on health care delivery without jeopardizing the overall quality of medical care for older and retired persons. The concept of self-responsibility for one's own health is not new. This concept, however, now takes on new meaning because the number of the very old is rising rapidly in the Oak Ridge retired community and because there is little in the way of historical experience and information to help interpret factors which may affect survival. This investigation should enable future epidemiologic studies of other Oak Ridge retired cohorts to maximize consideration relative to implications of relationships between socioeconomic indicators and health.

In view of the increasing attention and emphasis being directed toward closer control of employee exposure to potentially hazardous materials in the workplace, it is anticipated that retirees will be used as a barometer to evaluate the impact of specific work-related exposures. For example, the theory of tortious negligence has been used in cases where workplace hazards have been strongly suspected to be the cause for illness or death. In such cases substantial damages have been awarded in civil suits for both active and retired workers (Mosser, 1985). This researcher assumes that this is undoubtedly the courts' "cause and effect" remedy of putting industry on notice that it is responsible for safeguarding the health of its workforce against occupational hazards.

This study has provided an illustration of single and combined analyses of data from three nuclear worker populations. This researcher believes that such analyses provide one of the most reliable bases for summarizing evidence of the effects occupational exposures have on one's overall health status.

The results of this study should be received with interest by the community of occupational epidemiologists. The HWE is something that is often mentioned in the context of studies of workers where the mortality rates of the worker population are compared to the rates of the U.S. population. This study offered the opportunity to see how the HWE operates in a relatively large population of retired workers. The fact that all workers in this study were retired allows the examination of the HWE in a group of people who are no longer working, yet still have a relatively good level of income. With the exception of the people who retired before age 62, one could probably generalize and say that the individuals in this study were still healthy enough to work, but did not continue to work because of their age. It could be seen from this study that the HWE continued to be evident after retirement in the workers who left the plant at age 62 and older.

Most occupational studies are initiated in order to determine whether there are any health hazards related to employment in an industry. The workers who yield the most information about any disease exposure relationship are usually the workers who have been employed the longest period of time in the industry, and thus have the highest potential for exposure to occupational hazards present at the facility. As demonstrated in this study of long-term workers (i.e., retirees) these workers are likely to show deficits of deaths when compared to the U.S. standard population for many years after retirement. In order to detect increases in death rates in these long-term worker populations, it may be necessary to use an unexposed worker group as a comparison, or to develop new ways to interpret the magnitude of the SMRs.

In conclusion, this investigation has assessed the HWE question by making use of a wide range of vital statistics and survey data currently available at the Center for Epidemiological Research, Oak Ridge Associated Universities, Oak Ridge, Tennessee. It is realized that some of the data sources used in this investigation did have limitations; nonetheless, this researcher is confident that the insight gained into health-related questions can in the future improve the health of older workers. However, this project has only set the stage for further follow-up of this retired cohort by other University of Tennessee health education scholars.

BIBLIOGRAPHY

BIBLIOGRAPHY

- "A Memorial Volume of Selections from the Reports and Writings of Farr." Vital Statistics, 1975, pp. 497-550.
- Ahluwalia, B., et al. "Blood Hormone Profiles in Prostate Cancer Patients in High-Risk and Low-Risk Populations." Cancer, Vol. 48 (1981), pp. 2267-2273.
- Altenderfer, M. E. "Relationship between Per Capita Income and Mortality in Cities of 100,000 or More Population." Public Health Report 1947, Vol. 62, p. 1681.
- Ames, R. G. and B. Trent. "Mobility of Diesel versus Non-Diesel Coal Miners: Some Evidence on the Healthy Worker Effect." British Journal of Industrial Medicine, May 1984, pp. 197-202.
- Andvord, K. F. "What Can We Learn by Studying Tuberculosis by Generations?" Nonsk Magizene for Laecuidenskaben, Vol. 91 (1930), pp. 642-660.
- Antonovsky, A. "Social Class, Life Expectancy, and Overall Mortality." Milsank Memorial Fund Quantity, Vol. 47 (1967), pp. 31-73.
- Arp, E. W., P. H. Wolf, and H. Checkoway. "Lymphocytic Leukemia and Exposures to Benzene and Other Solvents in the Rubber Industry." Journal of Occupational Medicine, April 1983, pp. 598-602.
- Atchley, R. C. "The Process of Retirement: Comparing Women and Men." In Women's Retirement. Ed. M. Szinovacz. Beverly Hills, CA: Sage, 1982.
- Austin, S. G. and A. R. Schnatter. "A Cohort Mortality Study of Petrochemical Workers," Journal of Occupational Medicine, April 1983, pp. 304-312.
- Baum, Herbert M. and Kenneth G. Manton. "National Trends in Stroke-Related Mortality." The Gerontological Society of America, Vol. 27 (1987), pp. 293-301.
- Baum, M. and R. C. Baum. Growing Old: A Societal Prospective. Englewood Cliffs, NJ: Prentice Hall, 1980.
- Benjamin, B. Social and Economic Factors Affecting Mortality. The HaGue and Paris: Mouton, 1965.
- Berkman, L. F. and S. L. Syme. "Social Network, Host Resistance, and Mortality: A 9-Year Follow-up of Alameda County Residents." American Journal of Epidemiology, Vol. 109 (1979), pp. 109-204.
- Blau, Z. S. "Old Age in a Changing Society." New York: New Viewpoints, 1973.

Boaz, R. F. and C. F. Muller. "The Validity of Health Limitations as a Reason for Deciding to Retire." Health Services Research Journal, Vol. 25 (1990), pp. 361-386.

Bourliere, F. "The Assessment of Biological Age in Man." Public Health Papers, 37, Geneva: World Health Organization, 1970.

Carpenter, Lucy, et al. "Health-Related Selection and Death Rates in the United Kingdom Atomic Energy Authority Workforce." British Journal of Industrial Medicine, Vol. 47 (1990), pp. 248-258.

Carpenter, A. V., et al. "Brain Cancer and Nonoccupational Risk Factors: A Case-Control Study Among Workers at Two Nuclear Facilities." American Journal of Public Health, September 1987, pp. 1180-1182.

Castelli, W. P., et al. "The Filter Cigarette and Coronary Heart Disease: The Framingham Study." Lancet, 1981, pp. 109-113.

Changes in Mortality Among the Elderly: U.S. 1940-1978. Dept. of Health and Human Services, National Center for Statistics, Publication No. 82-1406. Washington, D.C.: Government Printing Office, March 1980.

Checkoway, H., et al. "Radiation, Work Experience, and Cause Specific Mortality Among Workers at an Energy Research Laboratory." British Journal of Industrial Medicine, August 1985, pp. 525-533.

Collins, J. F. and C. K. Redmond. "The Use of Retirees to Evaluate Occupational Hazards." Occupational Medicine, Vol. 18 (1976), pp. 595-602.

_____. "The Use of Retirees to Evaluate Occupational Hazards: II Comparison of Case Specific Mortality By Work Area." Occupational Medicine, Vol. 20 (1978), pp. 260-266.

Committee on the Biological Effects of Ionizing Radiations, The Effects on Populations of Exposure to Low Levels of Ionizing Radiation (BEIR V): 1990 (National Academy Press, Washington, D.C., 1990), p. 136, 406-409.

Correa, P., et al. "Passive Smoking and Lung Cancer." Lancet, 1983, pp. 1525-1536.

Cottrell, F. and R. C. Atchley. "Women in Retirement: A Primary Report." Oxford, OH: Scripps Foundation for Research in Population Problems, 1969.

Cragle, D. L., et al. "A Retrospective Cohort Mortality Study Among Workers Occupationally Exposed to Metallic Nickel Powder at the Oak Ridge Gaseous Diffusion Plant." In Nickel in the Human Environment, ed. F. W. Sunderman. New York: Oxford University Press, IARC Scientific Publication No. 53 (1984), pp. 57-63.

_____. "Mortality Among Workers at a Nuclear Fuels Production Facility." Journal of Industrial Medicine, Vol. 14 (1988), pp. 379-401.

- Crimmins, E. M. "Life Expectancy and the Older Population: Demographic Implications of Recent and Prospective Trends in Old Age Mortality." Research on Aging, Vol. 6 (1984), pp. 490-514.
- Cutler, R. G. "Evolution of Human Longevity and the Genetic Complexity Governing Aging Rate." National Institutes of Health Publication No. 81-2194. Washington, D.C.: U.S. Department of Health and Human Services, 1975, pp. 673-677.
- Developments in Aging: 1981. U.S. Senate, Special Committee on Aging. Washington, DC: Government Printing Office, Vol. 1 (1982).
- Doll, R. and A. B. Hill. "The Study of the Aetiology of Carcinoma of the Lung." British Medical Journal, 1952, pp. 1271-1286.
- Dupree, E. A., et al. "Mortality Among Workers at a Uranium Processing Facility: The Linde Air Products Company Ceramics Plant, 1943-1949." Scandinavia Journal of Work Environmental Health, Vol. 13 (1987), pp. 100-107.
- Enterline, P. E. and V. Henderson. "The Health of Retired Fibrous Glass Workers." Archives of Environmental Health, Vol. 30 (1975), pp. 113-116.
- Fillenbaum, G. G. "Social Context and Self Assessments of Health Among the Elderly." Journal of Health and Social Behavior, Vol. 20 (1979), pp. 45-51.
- Fisher, R. A. Smoking: The Cancer Controversy. Edinburgh and London: Oliver and Boyd, 1959.
- Fox, A. J. "Socio-Demographic Mortality Differentials: New Longitudinal Perspectives." Rev. Epiderm of Sante, Vol. 35 (1987), pp. 20-27.
- Frome, E. L., D. L. Cragle, and R. W. McLain. "Mortality Among a Cohort of World War II Nuclear Industry Workers in Oak Ridge, Tennessee." Nuclear Industry Workers Radiation Research, 1990 (unpublished).
- _____. "Poison Regression Analysis of the Mortality Among a Cohort of World War II." Nuclear Industry Workers Radiation Research, 1990 (unpublished).
- Frost, W. H. "The Age Selection of Mortality from Tuberculosis in Successive Decades." American Journal of Hygiene, Vol. 30 (1939), p. 96.
- Ghanadian, R., K. M. Puah, and E. P. M. O'Donogluo. "Serum Testosterone and Dihydrotestosterone in Carcinoma of the Prostate." British Journal of Cancer, Vol. 39 (1979), pp. 696-699.
- Greenwald, P. "Prostate." In Cancer Epidemiology and Prevention, ed. D. Schottenfeld and J. F. Fraumeni. Philadelphia: W. B. Saunders, 1982, p. 839.

- Greenwood, M. The Natural Duration of Cancer, Reports on Public Health and Medical Subjects. London: Her Majesty's Sanitary Office, Vol. 33 (1926), pp. 1-26.
- Grossman, M. The Demand for Health: A Theoretical and Empirical Investigation. New York: National Bureau of Economic Research, 1972.
- Guy, W. A. "On the Causes Which Determine the Choice of an Employment: Being an Addition to the Essays on the Influence of Employments Upon Health." Journal of Statistical Sociology, 1845, pp. 351-353.
- Hadley, J. and A. Osei. "Does Income Affect Mortality? An Analysis of the Effects of Different Types of Income on Age/Sex/Race-Specific Mortality Rates in the United States." Medical Care, Vol. 20 (1982), pp. 901-914.
- Harris, L. Aging in the Eighties: America in Transition. Washington, DC: National Council on the Aging, 1981.
- Health-U.S. 1988. Department of Health and Human Services, Public Health Service Center for Disease Control, National Center for Health Statistics, Publication No. 89-1232. Washington, D.C.: Government Printing Office, March 1989.
- Hendricks, J. and D. C. Hendricks. Dimensions of Aging: Readings. Cambridge, MA: Winthrop Publishers, Inc., 1979.
- Hickey, J. L. S., D. Crawford-Brown, and W. G. Tankersley. Occupational Exposures of Workers to Chemicals and Radiation During Uranium Processing at the Linde Ceramics Plant, 1943-1949. Oak Ridge, TN: Oak Ridge Associated Universities Technical Report No. 243, 1984.
- "Historical Roots of the Healthy Worker Effect." Journal of Occupational Medicine, Vol. 28 (1986).
- Hueper, W. C. Occupational and Environmental Cancers of the Respiratory System. New York: Springer-Verlag, 1966.
- Kilpatrick, S. J. "Mortality Comparisons in Socioeconomic Groups." Journal of Applied Statistics, Vol. 12 (1963), pp. 65-68.
- Kitagawa, E. M., and P. M. Hauser. Differential Mortality in the United States. Cambridge, MA: Harvard University Press, 1973.
- Laroque, P. "The Age of Retirement: Social and Economic Aspects." Vie Sociale, Vol. 8 (1975), pp. 480-503.
- Levin, M. L. "The Occurrence of Lung Cancer in Man." Acta Unio. Internationals Contra Cancrum, Vol. 9 (1953), pp. 531-541.

- Lilienfeld, A. M. and D. E. Lilien. "A Century of Case-Control Studies." Journal of Chronic Diseases, Vol. 32 (1979), pp. 5-13.
- Mandel, J. S. and L. M. Schuman. "Epidemiology of Cancer of the Prostate." In Reviews in Cancer Epidemiology, ed. E. M. Lilienfeld. Amsterdam: Elsevier, Vol. 1 (1980).
- Martin, G. M. "The Pathobiology of Aging." University of Washington Journal of Medicine, Vol. 5 (1979), pp. 3-10.
- McLain, R. and E. L. Frome. "A System for the Analysis of Cohort Mortality Data." Proceedings of the Eleventh Annual SAS Users Group International Conference, 1985, pp. 874-876.
- McMichael, A. J. "Standardized Mortality Ratios and the Healthy Worker Effect: Scratching Beneath the Surface." Journal of Occupational Medicine, March 1976, pp. 165-168. ✓
- Mechanic, D. Medical Sociology. 2nd ed. London: Collier MacMillan Publishers, 1978.
- Minkler, M. "Research on the Health Effects of Retirement." Journal of Health and Social Behavior, Vol. 22 (1981), pp. 117-130.
- Mishina, T., et al. "High Risk Group for Prostatic Cancer by Matched Pair Analysis." Nippon Hinyokika Gakkai Zasshi, Vol. 72 (1981), p. 1256.
- Monson, R. R. "Analysis of Relative Survival and Proportional Mortality." Computer and Biomedical Research, Vol. 7 (1974), pp. 325-332.
- _____. "Observations on the Healthy Worker Effect." Journal of Occupational Medicine, Vol. 28 (1986), pp. 425-433. ✓
- Monson, R. R. and L. J. Fine. "Cancer Mortality and Morbidity Among Rubber Plant Workers." Journal of the National Cancer Institute, Vol. 61 (1978), pp. 1047-1052.
- Moriyama, I. M. and L. Guralnick. Trends and Differentials in Mortality. New York: Milbank Memorial Fund, 1956.
- Mosser, Jerry L. "Monitoring Employee Exposures Limits Liability, Morale Problems." Occupational Health and Safety, May 1985, pp. 30-32.
- Nagi, M. H. and Stockwell. "Socioeconomic Differentials in Mortality by Cause of Death." Health Services Report No. 88, 1973, pp. 449-465.
- Orcutt, G. H., et al. "Does Your Probability of Death Depend on Your Environment? A Microanalytic Study." American Economic Review, Vol. 67 (1977), p. 260. ✓
- Ott, M. G., et al. "Mortality Among Individuals Occupationally Exposed to Benzene." Archives of Environmental Health, Vol. 33 (1978), pp. 3-10.

Palmore, E. "Health and Social Factors Related to Life Satisfaction." Journal of Health and Social Behavior, Vol. 13 (1972), pp. 68-80.

Palmore, E. B., et al. Retirement: Causes and Consequences. New York: Springer, 1985.

Palmore, E. B., G. G. Fillenbaum, and L. K. George. "Consequences of Retirement." Journal of Gerontology, Vol. 39 (1984), pp. 109-116.

_____. "Predictors of Retirement." Journal of Gerontology, Vol. 37 (1982), pp. 773-742.

Piscator, M. "Role of Cadmium in Carcinogenesis with Special Reference to Cancer of the Prostate." Environmental Health Perspective, Vol. 40 (1981), p. 107.

Polednak, A. P. and E. L. Frome. "Mortality Among Men Employed Between 1943 and 1947 at a Uranium Processing Plant." Journal of Occupational Medicine, Vol. 23 (1981), pp. 169-178.

Ross, R. K., A. Paganini-Hill, and B. E. Henderson. "The Etiology of Prostate Cancer: What Does the Epidemiology Suggest?" Prostate, Vol. 4 (1983), p. 333.

Rotkin, E. K. "Studies in the Epidemiology of Prostatic Cancer: Expanded Sampling." Cancer Treatment Report, Vol. 61 (1979), p. 173.

Rowland, K. F. "Environmental Events Predicting Death for the Elderly." Psychological Bulletin, Vol. 84. (1977), pp. 349-372.

Selvin, S., S. T. Sacks, and D. W. Merrill. "Patterns of United States Mortality for Selected Causes of Death." Physics, a publication of the Computer Science and Mathematics Division of Lawrence Berkeley Laboratory, University of California, November 1980, pp. 44-49.

Shindell, S., R. F. Weisberg, and Giefer, E. E. "The Healthy Worker Effect: Fact or Artifact?" Journal of Occupational Medicine, Vol. 20 (1978), pp. 809-811. ✓

Schuman, L. M. and J. S. Mandel. "Epidemiology of Prostatic Cancer in Blacks." Preventative Medicine, Vol. 9 (1980), p. 630.

Smith, Wrynn. A Profile of Health and Disease in America. New York, NY: Facts on File Publications, 1987.

Sterling, T. D. and J. J. Weinkam. "Extent, Persistence, and Consistency of the Healthy Worker or Healthy Person Effect by All and Selected Causes of Death." Journal of Occupational Medicine, Vol. 28 (1986), pp. 349-352. ✓

VITAE

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