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Mortality Experience of a Cohort of Rubber Workers, 1964-1973



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In 1970, the United Rubber Workers Union and six major rubber products manufacturing companies in the United States agreed to undertake joint occupational health programs. As a result of this pioneering effort, comprehensive studies of work related health problems have been initiated. This article presents the results of a cohort mortality analysis for a single rubber manufacturing plant located in Akron, Ohio. The objective of this study was to explore whether the general mortality experience of rubber workers is greater than in other industries or in the general population.

Design of the Study

The basic approach used in the present analysis was a historic prospective study design. The population at risk (PAR), conveniently called "the 1964 Cohort", was defined as follows: any Person who, as of January 1, 1964, was 40 or more years of age and was an active or living retired hourly worker from the plant under study. The mortality experience of the population at risk was observed for the period of ten years, from January 1, 1964 to December 31, 1973.

Procedures used to collect the necessary data for the reconstruction of the PAR required a thorough check of

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various company and union records. A large number of death certificates were collected from the company and, in the process of follow-up of the cohort, the remainder from bureaus of vital statistics of several states. The causes of death were coded by a trained nosologist according to the Eighth Revision of the International Classification of Diseases. Follow-up of the cohort is 96.7% complete. The remaining 3.3% of workers in the cohort will be followed-up in a subsequent study.

The study was designed so that mortality experience among active and retired workers could be examined separately. Since many workers retire prior to age 65, we obtained information on age and date of retirement for all retirees in the cohort. Workers were treated as active until the time of retirement and as retirees thereafter, regardless of age. It was felt that this design would allow for better study of active versus retired mortality experience than would an attempt to differentiate between the two groups by age for normal retirement.

Methods

Overall and age specific death rates were calculated for all deaths and for deaths due to selected causes. These rates were expressed as standardized mortality ratios (SMRs). The expected number of deaths for each five-year age group was calculated by multiplying the number of person years at risk in that age group by the age-race-specific death rate in the standard population for the

same age group for the cause or group of causes of interest. The SMR, then, is seen to be the ratio of the death rate in the population at risk (PAR) to the death rate that would have occurred in the PAR if deaths occurred at the same age-specific rates as in the standard.

To obtain the expected number of deaths for an age range longer than five years, the constituent five-year figures are added together. To examine whether the difference between the observed and expected number of deaths was due to chance alone, a chi-square test of significance was calculated for each of the two age-ranges 40-64 and 65-84 and for the entire range 40-84. Unless otherwise noted, for all SMRs presented in this paper, the standard population used is the 1968 U.S. population of comparable age, race, and sex.

The use of the general U.S. population as a standard in studies of the morbidity or mortality of an industrial population has been recognized as one of the major shortcomings of a study such as this one. This is because this standard population consists of all persons, working, not working, retired, chronically ill, institutionalized, physically handicapped, among other conditions, while workers are, by virtue of the fact that they are working, healthier than the remainder of the U.S. general population. This favorable selection operates not only at the time of a preemployment physical examination which is routinely performed in most industries, but also in selecting particular occupations in

which the worker is capable of performing. Because of this selection, the mortality experience of an industrial population is expected to be more favorable than that of the general population, giving rise to the phenomenon called the "healthy worker effect".

For comparative purposes, a general industrial population consisting of all industrial workers in the U.S. would be a more preferable standard population. In a study¹ of mortality by occupation and industry conducted in 1950 by the U.S. Department of Health, Education, and Welfare (HEW), standardized mortality ratios for various industries and occupations were calculated using workers employed in all manufacturing industries as the standard. Although several problems, mainly related to incompleteness of data, were encountered in the conduct of this study, it is the only one known to us in which the standard population consisted of all U.S. industrial workers. If such a standard population was available as of a more recent year, it would be preferable to the U.S. general population as a standard. However, since recent data for such an ideal standard population are not available, the use of the U.S. population has been common practice in studies of this type.

Results of Related Studies

During the last several decades there has been a growing awareness of occupationally related health hazards, and numerous mortality studies of industrial populations have been conducted. Industries which have been investigated in some depth include the following: asbestos, cotton textile, steel, chemical, coal and uranium mining, and some others, including the rubber industry. Cohort mortality studies of industrial populations are limited in number, and in the U.S. and Great Britain, most of these studies calculated mortality indices based on the general population as the standard.

The overall mortality experience of rubber workers has been examined in several studies. SMRs for all causes which have been reported for the rubber industry range from 86 to 99. The aforementioned HEW study,¹ using the U.S. industrial population as the standard, reported an SMR of 86 for the rubber industry. From a study of a cohort of over 13,000 rubber workers in Akron followed from 1940 to 1971,² the SMR was

Age at Death	White Males	Nonwhite Males	Total Males	%
40-44	1045	17	1062	12.9
45-49	799	20	819	12.2
50-54	1002	15	1017	12.0
55-59	1314	24	1338	15.5
60-64	1291	14	1305	15.2
65-69	1310	10	1320	15.4
70-74	874	10	884	10.1
75-79	415	11	426	5.2
80-84	132	4	136	1.5
Total	8412	100.0	8512	100.0

reported to be 86, using the U.S. general population as the standard. In a group life insurance study for the period 1955 to 1964, the U.S. Society of Actuaries found an SMR of 89 for rubber workers. A recently reported study⁴ of mortality in the rubber and cablemaking industries in Great Britain for the period between 1968 and 1971 found an overall SMR of 97. This study was based on over 40,000 workers employed on January 1, 1967, in 381 firms throughout the country. The standard population used was that for England and Wales. For a cohort of 6678 male rubber workers in Akron followed from 1964 through 1972,⁵ the SMR was 99 for the age range 40 to 84, based on U.S. general population data. The definition of that cohort of 6678 workers is very similar to that for the cohort of rubber workers presented in this paper.

For informative purposes we present some all-causes SMRs which have been reported for other industries. An SMR of 123 was reported for chromate workers for the period of 1937 to 1960.⁶ For 5370 uranium workers, all races combined,⁷ an SMR of 119 was found for the period 1950 to 1960. Among white male

workers employed between 1948 and 1951 and followed through 1963,⁸ an SMR of 112 was found for asbestos products workers employed in 10 industries, contrasted with an SMR of @ among cotton textile workers. An SMR of 82 was reported for a cohort of over 59,000 steelworkers followed for nine years.⁹ The general population of the local county was used as the standard in this study.

The above discussion refers to overall mortality. Several of the aforementioned studies of rubber workers have produced results for specific causes of death which are of interest. Mancuso's study^{10 11} of mortality in the state of Ohio suggested that there was an elevated proportion of deaths due to cancers of the respiratory, genitourinary, and central nervous systems among workers of the rubber and plastics industry as compared to workers in other industries. Subsequently, he reported an excess mortality from malignant neoplasms of the gall bladder, bile ducts, and salivary glands in a cohort of 1877 rubber workers followed from 1940 through 1968.¹³

In Great Britain, Case reported in

Age at Death	White Males	Nonwhite Males	Total Males	%
40-44	10.3	0.7	11	0.3
45-49	12.3	2.2	14.5	2.3
50-54	3.5	5.2	8.7	3.6
55-59	7.1	11.9	19	7.3
60-64	12.9	17.0	29.9	13.1
65-69	19.2	22.2	41.4	19.4
70-74	22.4	19.3	41.7	22.2
75-79	20.1	12.6	32.7	19.7
80-84	12.2	8.9	21.1	12.1
Total	2373	135	2508	100.0

Table 3. — Grouped Causes of Death Among White Male Members of the 1964 Cohort, 1964-1973
Age-Standardized Mortality Ratios (SMR).

ICDA* Disease Category	40-64		65-84		40-84	
	Observed Deaths	SMR	Observed Deaths	SMR	Observed Deaths	SMR
000-999 All causes	619	92	1754	95	2373	94
000-136 Infective & parasitic disease	3	55	10	87	13	76
140-149 M.N. of buccal cavity & pharynx	5	54	4	47	9	50
150-159 M.N. of digestive organs & peritoneum	35	97	116	112	152	108
160-163 M.N. of respiratory system	47	87	73	75	120	80
170-174 M.N. of bone, connective tissue, skin, and breast	1	28	7	106	8	78
180-189 M.N. of genitourinary organs	13	105	73	115	86	113
190-199 M.N. of other and unspecified sites	12	125	15	153	27	86
200-209 M.N. of lymphatic & hematopoietic tissues	12	93	40	138	52	124
210-239 Benign neoplasms of unspecified nature	28	108	4	125	6	119
240-279 Endocrine, nutritional, & metabolic diseases	15	122	37	198	52	108
280-289 Dis. of blood & blood-forming organs	14	93	7	189	8	162
290-315 Mental disorders	3	73	2	65	5	69
320-389 Dis. of nervous system in sense organs	8	153	3	77	16	98
393-396 Chronic rheumatic heart disease	9	112	16	170	25	143
400-404 Hypertensive diseases	5	103	22	102	27	102
410-413 Ischemic heart disease	272	99	745	94	1017	95
430-438 Cerebrovascular disease	48	138	194	95	242	102
470-486 Influenza and pneumonia	5	32	38	60	43	54
490-493 Bronchitis, emphysema, asthma	15	81	58	93	73	89
500-519 Other respiratory diseases	8	122	16	79	24	89
520-577 Dis. of the digestive system	24	62	54	90	78	79
680-709 Dis. of skin and subcutaneous tissue	0	0	1	85	1	64
710-738 Dis. of musculoskeletal system and connective tissue	1	72	3	113	4	99
780-796 Symptoms and ill-defined conditions	5	67	23	164	28	130
800-999 Accidents, poisoning, and violence	40	75	51	85	91	82
All other causes	26	70	137	97	163	91

*International Classification of Diseases, Eighth Revision.

+Malignant Neoplasms.

‡ = $p < 0.05$, + = $p < 0.01$, * = $p < 0.001$

Statistical test used to determine probability, p , was Chi Square: $\chi^2 = \frac{(\text{observed}-\text{expected})^2}{\text{expected}}$

Table 4. — Deaths from Selected Malignant Neoplasms Among White Male Members of the 1964 Cohort, 1964-1973
Age-Standardized Mortality Ratios (SMR).

ICDA* Disease Category	40-64		65-84		40-84	
	Observed Deaths	SMR	Observed Deaths	SMR	Observed Deaths	SMR
150 M.N. of esophagus	1	27	7	99	8	76
151 M.N. of stomach	8	123	26	122	34	122
153 M.N. of large intestine	12	109	41	111	53	116
154 M.N. of rectum	4	90	10	80	14	73
155 M.N. of liver	0	0	1	116	1	63
156 M.N. of gallbladder	1	91	3	80	4	63
157 M.N. of pancreas	1	10	2	127	3	122
161 M.N. of lung	1	7	23	127	24	76
162 M.N. of trachea, bronchus, & lung	1	2	11	152	12	63
185 M.N. of bladder	1	12	4	122	5	115
188 M.N. of prostate	1	67	1	122	2	119
189 M.N. of testis & unspecified male genital organs	1	12	1	122	2	117
191-192 M.N. of female genital tract, nervous system	1	12	1	122	2	62

*International Classification of Diseases, Eighth Revision.

+Malignant Neoplasm.

‡ = $p < 0.05$

Statistical test used to determine probability, p , was Chi Square: $\chi^2 = \frac{(\text{observed}-\text{expected})^2}{\text{expected}}$

1954¹⁴ that rubber workers were at increased risk of developing cancer of the bladder in connection with the use of α - and β -naphthylamine as antioxidants. These findings were confirmed by other investigators^{15,16} who identified particular work areas in the industry at greatest risk. Little evidence has been obtained of an excess of bladder tumors among rubber workers in the U.S. However, some studies¹⁸ indicate that there may be an increased risk of bladder cancer among rubber workers in Akron and Massachusetts.

A recently reported study in Great Britain⁴ suggests an excess of cancer of bronchus and lung in tire manufacture, pointing out two problem areas which require further study. These two areas are: (1) moulding, press, autoclave, and pan curemen, and (2) finished goods, packaging, and dispatch.

In a study of another group of rubber workers in Akron,⁵ an excess mortality was found for malignant neoplasms of the stomach and prostate, and for neoplasms of the lymphatic and hematopoietic tissue. Unpublished data* on the mortality of rubber workers identifies some specific work areas with an excess of deaths due to certain causes. For instance, an excess of cancer of bronchus and lung was found for workers who cure tires, while for the excess of leukemia deaths, no particular operations within the industry could be singled out.

In most of the above reviewed cohort studies in the rubber and other industries, the overall and cause-specific SMRs were based on data for the general population of the country or a local political subdivision. In the published reports on these studies some discussion was devoted to the phenomenon of the healthy worker effect as an inevitable shortcoming when studying employed populations.

However, none of these studies distinguished active worker mortality experience from retired worker mortality experience, particularly in the case of workers who retired before age 65. The study presented here distinguishes the mortality experience of all workers combined from that of active workers and that of retired workers. Particular attention is given to the mortality of workers who retired prior to age 65.

Results

Study Population. — Only the male

members of the 1964 Cohort were included in the present analysis. The distribution of this all male PAR by age group and color is given in Table 1. Of the total 8938 males, 8418 or 94% are white. As of January 1, 1964, about one-third of all males belonged to each of the following age groups: 40-54, 55-64, and 65-84. Although this holds for white males, it can be seen that non-white males are present in higher proportion in the younger age groups. The distribution of deaths by age at death for the cohort is found in Table 2. Of the 8418 white males, 2373 or 28% are known to have died during the ten year period. For black males, 135 of 520, or 26% are known to have died during the period of observation. Also, we note that 98.4% of the cohort had 10 or more years of service.

Deaths Among Male Hourly Workers. — We first analyzed mortality among all males, white and non-white combined. The main purpose for this analysis was to allow a general comparison of results from this study with those reported in 1974 for another population of rubber workers in Akron, Ohio.⁵ Definitions for the two PARs are very similar, and the plants under study are in the same city. The two PARs consist of workers from two different companies. Members of one PAR may have been employed, at some previous point in time, with the other company. Also, there are slight differences between the two PARs in average age at hire, raw materials used in the plants, and other factors which may have an effect on mortality. For the above reasons the comparison of mortality experience between the two PARs is not complete, and must be regarded as preliminary. We anticipate doing a more detailed comparison of mortality experience among workers employed in different rubber plants at some future date. SMRs were calculated using the all males combined segment of the 1968 U.S. general population.

The all causes SMRs for ages 40-64 and 40-84 are, respectively, 89 and 93. The corresponding SMRs for the other cohort, just referred to, are 93 and 99, respectively. The slight differences in the overall SMRs between the two cohorts cannot be explained with any degree of confidence at present. The fact that the overall SMRs for the cohort reported here are lower than for the other does

Table 3. — Deaths from Neoplasms of Lymphatic and Hematopoietic Tissues Among White Male Members of the 1964 Cohort, 1964-1973
Age Standardized Mortality Ratios (SMR)

ICD-9	Disease Category	40-64		65-84		40-84	
		Observed Deaths	SMR	Observed Deaths	SMR	Observed Deaths	SMR
200	Lymphatic neoplasms	2	12	1	10	3	122
201	Leukemia	2	12	1	10	3	122
202	Myeloid leukemia	2	12	1	10	3	122
203	Lymphatic leukemia	1	6	0	0	1	152
204	Myeloid leukemia	1	6	0	0	1	152
205	Lymphatic leukemia	0	0	0	0	0	0
206	Myeloid leukemia	0	0	0	0	0	0
207	Other (unspecified) leukemia	0	0	0	0	0	0
208-209	Other neoplasms of lymphatic & hematopoietic tissue	2	12	1	10	3	122
210	Other neoplasms of lymphatic & hematopoietic tissue	2	12	1	10	3	122

* International Classification of Diseases, Eighth Revision

t = p < 0.05, + = p < 0.01, * = p < 0.001

Statistical test used to determine probability, p, was Chi Square: $\chi^2 = \frac{(\text{observed}-\text{expected})^2}{\text{expected}}$

not necessarily imply that male workers in this company are healthier than male workers in the other company. We feel that a direct comparison of SMRs between the two cohorts should not be made at this point because of the method of standardization used.

However, some similarities of the cause-specific SMRs between the two cohorts of rubber workers are of interest, such as: (a) An excess of observed deaths was found for the 40-64 and 40-84 age ranges in both cohorts for the following causes: cancers of the stomach (151)*, large intestine (153), and prostate (185); and lymphosarcoma (200), diabetes mellitus (250), and suicides (E950-E959); (b) A lower than expected number of deaths was observed for the two age ranges in both cohorts for these causes: cancer of the respiratory system (160-163), chronic respiratory disease (490-493), accidents (E800-E949 plus E960-E999), and the group "all other causes".

Although the mortality experience in the two cohorts appears to be generally similar, the differences should be further investigated. These differences may be

due to differences in environmental exposure, or in race composition of the workforce, or perhaps in the method of standardization. In addition, the rather broad grouping "all other causes" should be examined in greater detail, and the analysis should be made race-specific for a more accurate comparison. As previously mentioned, further work will be required to complete an inter-plant comparison of the mortality experience of rubber workers.

Deaths Among White Male Hourly Workers. — The well recognized difference in mortality experience between white, black, and other races prompted us to perform race specific analyses. Since the general U.S. population data for black and other non-white males separately were not available at the time of this study, we restricted the analysis to white males only. Calculation of SMRs for white male hourly workers was based on the 1968 U.S. white male population.

As seen in Table 3, the SMR for all causes of death for white male members of the 1964 Cohort is 92 for the 40-64 age group, 95 for the 65-84 age group

Table 6. — Deaths from Selected Non-Neoplastic Causes Among White Male Members of the 1964 Cohort, 1964-1973
Age Standardized Mortality Ratios (SMR)

ICD-9	Disease Category	40-64		65-84		40-84	
		Observed Deaths	SMR	Observed Deaths	SMR	Observed Deaths	SMR
250	Diabetes mellitus	13	130	35	113	48	117
410	Acute myocardial infarction	221	110	481	103	702	105
440	Arteriosclerosis	2	96	32	112	34	111
571	Cirrhosis of liver	15	66	15	89	30	76
950-959	Suicide	16	120	14	126	30	122

* International Classification of Diseases, Eighth Revision.

Table 2. — Grouped Causes of Death Among White Male Members of the 1964 Cohort, 1964-1973, Considering Only Retired Experience
Age-Standardized Mortality Ratios (SMR)

ICDA ^a	Disease Category	40-64		65-84	
		Observed Deaths	SMR	Observed Deaths	SMR
000-999	All causes	299	102	175	95
000-136	Infective & parasitic disease	8	75	10	87
140-149	M.N. of buccal cavity & pharynx	1	21	2	17
150-159	M.N. of digestive organs & peritoneum	17	152	116	112
160-163	M.N. of respiratory system	50	217	76	118
170-174	M.N. of bone & connective tissue	1	10	1	9
	Skin & breast	1	10	1	9
180-189	M.N. of genitourinary organs	1	21	7	112
190-199	M.N. of other unspecified sites	1	21	7	112
200-209	M.N. of lymphatic & hematopoietic tissue	1	10	1	9
210-239	Benign neoplasms of unspecified sites	1	10	1	9
240-279	Endocrine, nutritional, & metabolic diseases	1	10	1	9
280-289	Diseases of blood & blood-forming organs	1	10	1	9
290-315	Mental disorders	1	10	1	9
320-389	Diseases of nervous system & sense organs	1	10	1	9
393-398	Chronic rheumatic heart disease	1	10	1	9
400-404	Hypertensive disease	1	10	1	9
410-413	Ischemic heart disease	112	120	72	91
430-435	Cerebrovascular disease	22	120	19	95
470-485	Infective pneumonia	1	10	1	9
490-493	Chronic bronchitis & asthma	1	10	1	9
500-519	Other respiratory diseases	1	10	1	9
520-577	Diseases of the digestive system	15	216	24	90
680-709	Diseases of skin & subcutaneous tissue	1	10	1	9
710-738	Diseases of musculoskeletal system & connective tissue	1	10	1	9
780-796	Symptoms & ill-defined conditions	1	10	1	9
800-999	Accidents, poisoning, and violence	11	113	51	89
	All other causes	12	111	17	96

^aInternational Classification of Diseases, Eighth Revision.

+Malignant Neoplasms.

‡ = $p < 0.05$, * = $p < 0.01$, ** = $p < 0.001$

Statistical test used to determine probability, p , was Chi Square: $\chi^2 = \frac{(\text{observed}-\text{expected})^2}{\text{expected}}$

and 94 for the entire cohort. While this table presents SMRs for all causes of death and for the usual grouping of causes suggested by the International Classification of Diseases, Tables 4-6 show SMRs for selected smaller groupings and individual causes. There is an excess of observed over expected deaths in one or both age ranges (40-64 and 65-84) in the PAR for certain neoplasms, discussed in (a) through (d) below:

(a) From Table 3, there is an excess of deaths due to malignant neoplasms (M.N.) of the digestive organs and peritoneum (150-159) in the 65-84 age range. Within this group of diseases (see Table 4), an excess of deaths is observed in both age ranges for M.N. of the stomach (151), large intestine (153), and pancreas (157). For M.N. of the liver (155), there is an excess of deaths in the upper age range. Other causes within this group show a deficit of deaths.

(b) We see from Table 3 that in both age ranges there is an excess of deaths due to M.N. of the genitourinary organs (180-189). Within this group of diseases, according to Table 4, there is an excess of deaths due to M.N. of the prostate (185) in both age ranges, and due to M.N. of the bladder (188) and other and unspecified urinary organs (189) in the 65-84 age range.

(c) The SMR is elevated for M.N. of other and unspecified sites (190-199) in the 40-64 age range (see Table 3). From Table 4, the same is true for M.N. of the brain and central nervous system (191-192).

(d) From Table 3, there is a statistically significant excess of deaths in the 65-84 age range due to neoplasms of the lymphatic and hematopoietic tissue (200-209). However, it is more important to notice from Table 5 that each individual cause within this group shows an excess of deaths in at least one of the two age ranges. In the 65-84 age range, the excesses are statistically significant for monocytic leukemia (206) and for the other neoplasms in this group (202, 208, 209), for which the U.S. figures were not available by individual categories.

We shall now consider non-neoplastic diseases for which an excess of deaths was observed. These are discussed in (a) through (g) below.

(a) The SMR is elevated for endocrine, nutritional, and metabolic diseases (240-279) in the 40-64 age range (see Table 3). Table 6 shows that for diabetes

Table 3. — Deaths from Selected Malignant Neoplasms Among White Male Members of the 1964 Cohort, 1964-1973, Considering Only Retired Experience
Age-Standardized Mortality Ratios (SMR)

ICDA ^a	Disease Category	40-64		65-84	
		Observed Deaths	SMR	Observed Deaths	SMR
150	M.N. of esophagus	1	112	2	103
151	M.N. of stomach	1	157	2	122
153	M.N. of large intestine	1	216	4	122
154	M.N. of rectum	1	216	1	9
155	M.N. of liver	1	216	1	10
156	M.N. of gallbladder	1	216	1	10
157	M.N. of pancreas	1	216	2	122
161	M.N. of lung	1	216	2	122
162	M.N. of bronchus, trachea & lung	1	216	2	122
185	M.N. of prostate	1	216	1	122
188	M.N. of bladder	1	216	1	122
189	M.N. of other & unspecified urinary organs	1	216	1	122
191-192	M.N. of brain and central nervous system	1	216	1	107

^aInternational Classification of Diseases, Eighth Revision.

+Malignant Neoplasms.

‡ = $p < 0.05$, * = $p < 0.01$

Statistical test used to determine probability, p , was Chi Square: $\chi^2 = \frac{(\text{observed}-\text{expected})^2}{\text{expected}}$

mellitus (250), which accounts for over 90% of the deaths in this disease group, the SMR is elevated for both age ranges.

(b) From Table 3 we see that the SMR is elevated for diseases of the blood and blood-forming organs (280-289) for the 65-84 age range.

(c) For diseases of the nervous system and sense organs (320-389), the SMR is elevated in the 40-64 age range.

(d) Also, we see that the SMR is elevated in one or both age ranges for the following: chronic rheumatic heart disease (393-398) (with the excess being statistically significant in the upper age range), hypertensive diseases (400-404), and cerebrovascular disease (430-438), with the excess of deaths in this last group being statistically significant in the 40-64 age range.

(e) The group "other respiratory diseases" (500-519) shows an excess of deaths in the 40-64 age range.

(f) From Table 6, we see that the SMR is elevated for acute myocardial infarction (410) in both age ranges, and for arteriosclerosis (440) in the upper age range.

(g) Also, the SMR for suicide (E950-E959) is elevated in both age ranges.

A deficit of deaths, however, was observed for some diseases of interest discussed below. From Table 3, a deficit of observed deaths for M.N. of the respiratory system (160-163) for both age groups is seen, the deficit in the upper age range being statistically significant. However, if one considers the age range 40-49, an SMR of 148 is found which emphasizes the masking effect of using broad age ranges. Statistically significantly fewer than expected deaths were observed in both age ranges for influenza and pneumonia (470-486) and in the 40-64 age range for diseases of the digestive system (520-577). There was also a deficit of deaths due to cirrhosis of the liver (571) in both age ranges, as shown in Table 6.

An unpublished study² of a cohort of white male rubber workers in Akron, Ohio showed results basically similar to those found in this study. The most noticeable difference is that the other study found a deficit of deaths from suicide, while an excess was observed in this study.

Deaths Among Retired White Male Hourly Workers. — In the manner of some other studies, we have presented and discussed SMRs for the cohort of

Table 9. — Deaths from Selected Non-Neoplastic Causes Among White Male Members of the 1964 Cohort, 1964-1973, Considering Only Retired Experience. Age Standardized Mortality Ratios (SMR).

ICD-9 Disease Category	40-64		65-84		All Ages	
	Observed Deaths	SMR	Observed Deaths	SMR	Observed Deaths	SMR
250 Diabetes mellitus	10	437*	35	113	45	135*
410 Acute myocardial infarction	89	200*	481	103	570	111*
440 Arteriosclerosis	1	167	32	112	33	113
571 Cirrhosis of liver	11	277*	15	89	26	125
950-959 Suicide	3	144	14	126	17	129

*International Classification of Diseases, Eighth Revision.

t = p < 0.05, + = p < 0.01, * = p < 0.001

Statistical test used to determine probability, p, was Chi Square: $\chi^2 = \frac{(\text{observed}-\text{expected})^2}{\text{expected}}$

Table 10. — Deaths from Selected Non-Neoplastic Causes Among White Male Members of the 1964 Cohort, 1964-1973, Considering Only Retired Experience. Age Standardized Mortality Ratios (SMR).

ICD-9 Disease Category	40-64		65-84		All Ages	
	Observed Deaths	SMR	Observed Deaths	SMR	Observed Deaths	SMR
250 Diabetes mellitus	10	437*	35	113	45	135*
410 Acute myocardial infarction	89	200*	481	103	570	111*
440 Arteriosclerosis	1	167	32	112	33	113
571 Cirrhosis of liver	11	277*	15	89	26	125
950-959 Suicide	3	144	14	126	17	129

*International Classification of Diseases, Eighth Revision.

t = p < 0.05, * = p < 0.001

Statistical test used to determine probability, p, was Chi Square: $\chi^2 = \frac{(\text{observed}-\text{expected})^2}{\text{expected}}$

hourly workers without differentiating between active and retired work status. However, the possibility of masking effect from using broad categories of age and cause of death should be recognized. This masking effect, which Mancuso¹² called a "dilution factor", should also be considered with respect to other factors besides age and cause of death. As he pointed out, an excess of deaths due to a certain cause among workers in a single department of an industry may not be apparent from examination of the death rate due to that cause in the industry as a whole, because of the dilution factor. Accordingly, we shall analyze mortality by work exposure as soon as the necessary data, which have been collected, are made suitable for analysis. We also became concerned that analyzing mortality experience without regard to whether the workers were active or retired might mask important information. For this reason we elected to analyze separately the active and retired mortality experience of white male workers to learn whether mortality ex-

perience differs between the two groups. Differences might be manifested in several ways.

First, if active workers in the 40-64 age range have a different mortality experience than workers who retire in this age range, the differentiation of SMRs between the two groups would lead to useful conclusions. Our feeling was that any assessment of the healthy worker effect might better be based on the mortality experience of active workers only, rather than on the combined active and retired population. Hence, the true magnitude of this effect is based on a population which separates presumably healthier active workers from the non-working retired individuals who, most likely, have high mortality rates. Furthermore, separation of early from disability retirement status will permit assessment of mortality experience among workers who retire prior to age 65, the age for normal retirement. This analysis will be reported in a subsequent paper. The present study deals with the examination of the above mentioned differences by separating only mortality ex-

perience of active workers from that of all retired workers, under 65 years of age.

We shall briefly discuss first the mortality experience of the active portion of the cohort, then we discuss that of the retired portion. Since workers in the 65-84 age range are virtually all retired, discussion in this section will be limited to the 40-64 age range unless otherwise noted.

The overall SMR for active white male hourly workers in the cohort is 61, based on a total of 320 deaths from 35,586 person-years experience. Since the overall SMR for the 40-64 age range is 92 (see Table 3), we conclude that a less favorable mortality experience among non-active workers in this age range is masking the true SMR for active workers. The healthy worker effect reported in other studies has usually been reflected by an SMR of 80 to 90 for the "working population". The SMR of 61 reported here for the active workers, on which we feel the healthy worker effect could be based, is substantially lower than these other figures and may, in part, be due to selecting out those most heavily exposed or unable to adapt to the conditions through early-voluntary and disability retirement. However, elevated SMRs have been found for certain causes of death in this active worker population. The causes for which an excess of deaths were observed in the active group, based on three or more deaths, are listed below.

Cause of Death (I.C.D.A. Code)	SMR
M.N. of the stomach (151)	101
M.N. of the respiratory system (160-163)	125
Lvrnphosarcoma (200)	117
Leukemia (204-207)	109
Suicide (950-959)	115

Note that all SMRs shown above are for white male active workers aged 40-64, except the SMR for M.N. of the respiratory system (160-163), which is based on the 40-49 age range.

Our expectation that workers who retired prior to the normal retirement age, 65, would experience less favorable mortality than active workers of the same age range seems to be correct. From Table 7, the overall SMR for retired workers 40-64 years of age is 202, indicating a highly statistically significant excess of deaths ($p < 0.001$). The SMR is based on 299 deaths from 5822 person years experience.

With respect to cause specific mor-

tality among retired workers, SMRs for grouped and individual causes of death are presented in Tables 7-10. These are organized in exactly the same manner as Tables 3-6 to facilitate comparison of SMRs for retired workers with SMRs for all workers. Comparison of results in the 65-84 age range between the two sets of tables is not very useful, since that component of the two groups is virtually identical. Comparison of results in the 40-64 age range emphasizes that retired workers in this age range have a markedly less favorable mortality experience than do active workers in this age range. This was to be expected, but the magnitude of the excess, an SMR of 202 as compared with 61 for the active workers in the same 40-64 age range, is the important point. We note again that these SMRs are for white males and adjusted by the indirect method for differences in age distribution.

With the exception of influenza and pneumonia (470-486) and those causes of death for which no deaths were observed, there was an excess of observed deaths for the age group 40-64 for each disease category listed in Tables 7-10. For about half of these disease categories, the excess is statistically significant. The most striking of the excesses are for malignant neoplasms of the respiratory system (160-163), genitourinary organs (180-189), and other and unspecified sites (190-199), and for endocrine, nutritional and metabolic diseases (240-279), chronic rheumatic heart disease (393-398), and cerebrovascular disease (430-438).

These findings emphasize the fact that further studies of this population are highly important. We plan to investigate the relationship of a large number of factors to the health and mortality experience of this population. These factors include the following: work history, reason for retirement prior to age 65, and causes of disability. We are currently investigating these relationships in a larger population involving a cohort of 31,000 workers employed any time since January 1, 1951.

We have made a preliminary investigation of the relationship between work experience and age at death among retirees. Summarizing the work history by Most Representative Department (MRD), defined as the department in which the worker spent the greatest portion of working time, we compared

the distribution of MRD between two groups: (1) retirees in the cohort who died prior to age 65 during the period of observation, and (2) retirees who were alive at the end point of the study, or survived to at least age 65. We found that the distribution of MRD was statistically significantly different between the two groups. We do not feel that the difference can be presently associated with specific causes of death. Of course, more detailed analytic studies will have to be done to examine this preliminary finding.

Summary

The analysis of mortality was carried out for all males regardless of race to allow comparison of results with those from a similar study of Akron rubber workers.⁵ Death rates for certain neoplasms, diabetes mellitus, cerebrovascular disease, arteriosclerosis, and suicide were shown to be in excess for at least one of the two age ranges, compared with the U.S. general population. The death rate due to all causes was lower than in the standard population, as reflected by SMRs of 89 and 93 for age ranges 40-64 and 40-84, respectively.

Because of the different mortality experience of different racial groups, we performed race-specific mortality analyses for this cohort. The analysis for white males was done first, as they are by far the largest race-sex group in the cohort. Unfortunately, suitable standard population data were not available for blacks. The death rate for all causes for white males, after adjusting for age differences, was lower in the cohort than in the U.S. general population for both the 40-64 and 65-84 age groups, as reflected by SMRs of 92 and 95, respectively.

For some causes of death, however, an SMR of greater than 100 was found for one or both age ranges, indicating an excess of deaths. These include the following: malignant neoplasms (M.N.) of the digestive organs and peritoneum, M.N. of the genitourinary organs, M.N. of other and unspecified sites, and neoplasms of the lymphatic and hematopoietic tissue. Among non-neoplastic diseases, an excess of deaths was found for these: endocrine, nutritional, and metabolic diseases, a group which includes diabetes mellitus; diseases of the blood and blood forming organs; diseases of the nervous system;

and the group other respiratory diseases. Again after adjusting for age, the death rate due to suicide was found to be higher for white males in the cohort than in the U.S. general population. Another study² of white male rubber workers in Akron, Ohio, showed similar results, except that a lower death rate for suicide was observed in that study population than in the U.S. general population.

We felt it necessary to separately analyze active and retired mortality experience in the 40-64 age range because of the possible masking effect or dilution factor which would be present if no distinction were made between the two groups. Of course, all mortality experience beyond age 65 occurs in the non-working population, since the mandatory retirement age is 65.

The all-causes SMR for white male active workers 40-64 years of age is 61, probably due to selecting out the weaker individuals by disability retirement leading to early death. This figure is considerably lower than the SMR of 80 to 90 which is generally held to reflect the "healthy worker effect". In spite of this SMR reflecting a low all-causes death rate among white male active workers, the death rate for some causes was elevated above that for the U.S. general population, after adjusting for age differences. These causes for which an excess of deaths was observed in the 40-64 age range include the following: M.N. of the stomach, M.N. of the respiratory system (in the 40-49 age range only), lymphosarcoma, leukemia, and suicide.

In contrast to this, an all-causes SMR of 202 was observed for white male retired workers 40-64 years of age. This indicates a highly statistically significant excess of deaths as compared to the U.S. general population. The excess of deaths among retired white males 40-64 years of age is even greater in comparison with the active worker population as the standard, with an all-causes SMR of 398.

Although there is an excess of deaths among retirees 40-64 years of age for

almost every cause shown in Tables 7-10, the most important result here is the great overall excess. As stated in the previous section, detailed studies of the relationship between this excess of deaths and other factors related to the worker are necessary.

The results of this study show that for certain causes of death and certain groups of workers, the death rate is higher than in the U.S. general population after adjustment for age difference among white males. No association of this fact with work exposure can be made at present. However, a comparison of work exposure summarized by Most Representative Department (MRD) between two groups of retirees indicates that such an association may exist. A noticeable difference in work experience measured by MRD was found between these two groups: (1) retirees in the cohort who died in the period of observation prior to age 65, and (2) retirees who were alive at the end point of the study, or survived to at least age 65. The fact that a difference in work experience between these two groups can be observed indicates to us a need for further study of the relationship between work experience and health of the worker.

*Numbers in parentheses which immediately follow a cause of death indicate the ICDA code(s) corresponding to the stated cause(s) of death.

†These workers include disability retirees, who have a health problem which prevents them from working, and early retirees, who may have retired voluntarily or because of a nondisabling health problem.

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