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An Epidemiologic Study of Mortality within a Cohort of Rubber Workers, 1964-72

A. J. McMichael, MD; R. Spirtas, M.S.; L. L. Kupper, Ph.D.

Interest in the health status of workers in the U.S. rubber industry was brought to a new focus in 1970. In that year, the Occupational Safety and Health Act (OSHA) was passed by Congress, and in the same year the United Rubber Workers Union negotiated with the six major U.S. rubber companies for a comprehensive study of work-related health problems.

An earlier and longstanding interest in the health of rubber-workers stemmed from knowledge of the physiological effects (often acute) of chemical compounds used in the industry.¹⁻³ The industry uses many chemicals, which "run the gamut of highly hazardous to innocuous".¹ The rapid evolution of rubber production technology entails a continuous change in chemicals used, and in reaction by-products produced.⁴ Among the compounds now or

previously used are some proven carcinogens and certain chemicals currently under investigation as carcinogens.⁶⁻¹¹

Certain morbidity and mortality trends among rubber-workers have been suggested in earlier studies. In Britain, in the 1950's, Parkes conducted an industry-wide study of sickness absenteeism, and found differences in the morbidity experience (for example, dermatitis) between production workers and office staff; further differences were observed among the various production groups.¹² In 1929-31, the British Registrar General reported that rubber workers showed a 10% total mortality excess, compared with national mortality data, and that the excess derived from cancer deaths.¹³ A similar mortality excess had been recorded in 1920-22.¹⁴

In the United States, a national study of occupational disability, based on Social Security data from the period 1959-62, showed that skilled and semi-skilled employees in the rubber industry had experienced a higher morbidity ratio for malignant neoplasms of the respiratory system, chronic rheumatic heart disease, emphysema, and arthritis, when compared with other industrial workers.¹⁵ The U.S. Department of Health, Education and Welfare had

previously published a figure showing that, compared to male workers in all manufacturing industries, male rubber-workers age 20 to 64, in 1950, had a 14% overall deficit of deaths.¹⁶ However, there was an 8% excess death rate from malignant neoplasms (especially of the bowel, 30%; respiratory system, 18%; and the lymphatic and hematopoietic tissues, 54%), chronic rheumatic heart disease (10%), and arteriosclerotic heart disease (15%). These data were necessarily incomplete, being based on the "Usual Occupation" as recorded on the death certificate. More recently, a group life insurance study by the U.S. Society of Actuaries, covering 1955-64, found an age-standardized mortality ratio of 89 (i.e. 11% deficit) for workers in rubber manufacturing.¹⁷

Mancuso, in 1947, reported an elevated proportion of deaths due to cancer for workers in the rubber and plastics industry in Ohio.¹⁸ In particular, he found a proportional mortality excess from cancers of the respiratory, genitourinary, and central nervous systems. Mancuso also reported a relative excess of neoplasms of the central nervous system among Ohio male residents, and demonstrated that the excess was located in Summit County (the

From the Departments of Epidemiology (Dr. McMichael) and Biostatistics (Dr. Spirtas and Kupper), Occupational Health Studies Group, School of Public Health, University of North Carolina, Chapel Hill, N.C.

Reprint requests to Dr. A. J. McMichael, Chapel Hill, NC 27514.

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principal center for U.S. tire-manufacturing industry), and was most dense in urban-dwelling males."

In a subsequent mortality study of a cohort of 1,877 rubber workers, followed historically from 1940-64, Mancuso reported that the overall mortality rates were higher for production workers than for office staff and that death rates for many causes (various malignant neoplasms, and diseases of the circulatory, respiratory, digestive, and genitourinary systems) were higher in the compounding, milling, calendering, and curing areas than in both the other production areas and in Ohio State in general.⁷ For example, he reported a five-fold excess of malignant neoplasms of the stomach among retired rubber workers, compared to Ohio State mortality data. Mancuso also observed a considerable variation among the various production departments for death rates from certain specific causes of death, thereby emphasizing the possible etiologic influence of localized factors in the work environment. He remarked upon the "dilution effect" which can occur when such a study makes no distinction between different groups of workers experiencing different exposures within an industry. (Mancuso's own comparative data for different groups of workers, however, is hampered by the small numbers of persons in the various exposure groups.)

Mancuso and Brennan subsequently extended the above cohort study through 1969, and reported findings suggestive of an excess mortality due to cancer of the gall bladder, bile ducts and salivary glands.¹⁰ The findings for these relatively rare cancers in rubber-workers have not yet been replicated elsewhere.

In 1954, Case and Hosker had reported an excess of bladder tumors in British rubber workers.⁸ Subsequently, despite removal of the presumed carcinogen (an antioxidant) from the production process, excess occurrence of bladder tumors in British rubber-workers was reported by Veys,²⁰ and, more recently, by Adelstein.²¹ Veys identified the areas in the tire plant of greatest risk (mixing, maintenance, stores and dispatch). In the U.S., firm evidence of a bladder cancer excess among rubber workers is still lacking. A population-based case-control study of bladder cancer in Massachusetts, estimated a relative risk of 1.6 for males working in the rubber industry.²² Guira reported on a series of 565 bladder

tumor cases diagnosed at four Akron hospitals between 1958-1967.²³ However, his estimate of a five-fold risk of bladder tumors among rubber-workers was compromised by the lack of a control group, the lack of information about the source population, and the non-adjustment for age, race and sex in calculating incidence rates.

Although a number of studies have reported excessive respiratory cancer mortality in other industries (e.g. the asbestos, chromate, arsenic, uranium mining, and steel foundry industries), the evidence regarding respiratory cancer deaths in U.S. rubber-workers is meager. The above-mentioned U.S. government report¹⁶ of an 18% excess respiratory cancer mortality, and Mancuso's finding of an excess death rate among compounding, milling and calendering workers, suggest there may be a respiratory cancer excess within the rubber industry. One outbreak of work-related respiratory illness has been documented in the U.S. rubber industry, in 1961, in which, at its peak, 312 (14%) of the plant's 2,225 workers were affected, subsequently leaving 32 (1.4%) permanently disabled.²⁴

From these various studies, the death rate from all causes within the U.S. rubber industry appears not to be elevated significantly, if at all. However, the literature suggests an excessive mortality from certain malignant neoplasms (bladder, lymphatic and hematopoietic tissues, stomach, large bowel, and possibly respiratory system and central nervous system), and from some types of cardiovascular disease.

Study Design

The results presented in this article are from an initial mortality study carried out within the research program negotiated between the United Rubber Workers and the six major U.S. rubber companies. When a series of epidemiologic studies is initiated within an industrial setting, an historical mortality study is commonly done first, for two reasons. Firstly, preexisting data on deaths is usually available both readily and systematically, along with data on the population at risk. Secondly, excess mortality represents a uniquely serious type of health problem. Such a study can determine whether there is an excess death rate from any or all causes, and whether any such excess is associated with certain exposure areas within the

industry

This present study used an historical prospective design. The cohort (or population at risk) comprised all the hourly (i.e. factory) active and retired male employees, age 40 to 84 at 1/1/64, within a major tire-manufacturing plant in Akron, Ohio. Working from company records of payroll, pensions, death claims, severance awards, transfers between hourly and salaried status, and employment costs, a cohort of 6678 male rubber workers was identified, and extensively cross-checked. (Female employees, comprising only 10% of the 1/1/64 population, were not included in the study.)

During the full nine-year period, 1964-72, 1783 life insurance death claims were paid on behalf of deaths occurring within the cohort. The completeness of the deaths enumeration was established by cross-checking internally against various company and insurance files, and, externally, against the files of the U.S. Internal Revenue Service. (This latter crosscheck entailed a random group of 250 members of the cohort, apparently alive Dec. 31, 1972. The initial tax-return search showed 221 (88%) were alive, and the other 29 were confirmed as alive by subsequent personal follow-up.)

Death certificates were obtained from the company's insurance carrier for all but nine (0.5%) of these 1783 deaths. Within this cohort, the only deaths ineligible for life insurance benefits would have been those among employees who quit from active employment during the 1964-72 period. (Eighty-four such exits occurred, mostly of men in the 40 to 49 age-range. A recent search of State Health Department records disclosed only two deaths among this group of quitters. For practical research purposes, therefore, the 1783 company-recorded death claims represent the total mortality within this cohort for the period 1964-72.)

The information relating to cause of death on the death certificates was coded by a National Center for Health Statistics nosologist, using the Eighth Revision of the International Classification of Diseases. The resultant cause of death coding of the mortality data was therefore directly comparable to the current U.S. national mortality data, as compiled by the National Center for Health Statistics.

The first phase of this mortality study

has sought to describe the mortality experience of the cohort, and to compare it with the "expected" mortality figures as derived from some standard population. The ongoing second phase of the study entails determining the complete employment (exposure) history of cohort members, and then comparing the mortality experience of the various exposure subgroups of workers.

This report contains, predominantly, the results of the first phase of the study — together with some additional mortality data from five other smaller plants within the same company, for the same period 1964-72.

Calculation of Expected Mortality Figure

The primary technique used for assessing the significance of the observed mortality within the cohort was to compare it to the mortality expected within that cohort, had the death rates at each age been the same as in a selected "standard" population. The ratio of observed to expected deaths is expressed as the Standardized Mortality Ratio (SMR):

$$SMR = \frac{\text{Observed deaths}}{\text{Expected deaths}} \times 100$$

In order to focus on work-related mortality hazards specific to the rubber industry, the ideal standard population would comprise all other industrial workers in the U.S. However, comparable and current mortality data is not available in sufficient detail either for different occupational groupings or for local geographic regions. For this reason, the U.S. male population was selected as the standard, and the published schedule of 1968 age-specific death rates was used to calculate expected mortality. (The year 1968 was chosen, as the midpoint of the 1964-72 period. Analysis of annual national death rates throughout the period showed that the 1968 mortality data was 3% higher than the period average, therefore producing a slight underestimation of SMRs within the study cohort.)

Because information on race was not systematically available for all members of the cohort, the standard U.S. population chosen was that of all males. Examination of the proportion of blacks

Age	Rubberworker Cohort ¹ (1964-72)	Steelworker Cohort ² (1953-61)	Ohio State ³ (1972)	U.S. ⁴ (1968)
45 - 54	852	907	540	980
55 - 64	2317	2166	2365	2310

* Adjusted to the estimated racial composition of the study cohort

1. Rates expressed per 100,000 person-years at risk.

2. Lloyd and Ciocco (25). Rates expressed per 100,000 person-years at risk.

3. Dept. of Health, State of Ohio (26)

4. U.S. Dept. of H.E.W., Nat. Center for Health Statistics (27)

Rates expressed per 100,000 population per annum

Age	Total person-years at risk, 1964-72 (1)	No. of Observed Deaths (2)	U.S. Male Death rate, 1968 (per 100) (3)	Expected Deaths (4) = (1) x (3)	Observed Expected (5) = (2) x (4)
40 - 44	2642.0	17	435.8	12.9	1.318
45 - 49	6388.5	42	757.0	49.0	0.857
50 - 54	7108.5	73	1224.9	87.1	0.838
55 - 59	7394.0	144	1914.9	141.6	1.017
60 - 64	8015.0	213	2923.4	234.3	0.910
65 - 69	7931.5	341	4253.3	337.7	1.010
70 - 74	6496.5	335	6453.1	419.2	0.918
75 - 79	3651.5	357	2653.8	333.3	1.071
80 - 84	1519.0	211	12,073.9	183.4	1.150
40 - 64	31,543.0	439	—	524.9	0.932 ²
65 - 84	13,799.5	1254	—	1273.5	1.016
40 - 84	51,346.5	1723	—	1798.5	0.991

1. Standard mortality figures are for 1968 U.S. national male population²

2. SMR (40-64) = $0.932 \times 100 = 93.2$

SMR (65-84) = $1.016 \times 100 = 101.6$

SMR (40-84) = $0.991 \times 100 = 99.1$

(14%) among a 20% random sample of the cohort suggested that the racial composition of the cohort was similar to that of the 1968 U.S. national male population within the same age-range (blacks = 10%).

Results

Age-specific all-causes death rates were calculated for the cohort for the period 1964-72. The rates are expressed per 100,000 person-years at risk, to avoid distortion due to the ageing of the cohort throughout the nine-year observation period. (The unit of denominator "at risk" observation, used in calculating age-specific rates, is not the complete nine-year experience of an individual, but is instead that portion of his total "at risk" experience that falls within the specified age-range (e.g. 45 to 54). Clearly, most individuals will contribute

"person-years at risk" to two adjacent 10-year age-ranges (e.g. 45 to 54, 55 to 64), as increasing age carries the individual across age boundaries.)

Table 1 compares the age-specific death rates of the cohort with those of three different types of comparison population — another industrial population, a regional population, and the national population. For the four populations, comparable death rates are only available for the active working age-range (45 to 64). The rates have been race-adjusted to the (estimated) racial composition of the rubber worker cohort. The steelworker mortality data, as published by Lloyd and Ciocco,²⁵ represents the mortality experience of an industrial population generally free of any excess of deaths (all-causes SMR = 82, with local county mortality data used as the standard).

With the exception of the death rate

Table 3. — Standardized Mortality Ratios (SMR) for Selected Causes of Death, for the Full and the "Active" Age-Range.

Cause of Death (I.C.D. Code ¹)	"Active" age-range (40-64)			Full age-range (40-84)		
	Deaths Observed	Deaths Expected	SMR	Deaths Observed	Deaths Expected	SMR
All Causes	429	524.9	93	1783	1795.5	99
All neoplasms (140-239)	110	103.5	101	351	336.9	104
Malignant neoplasms (140-209)	109	107.3	100	344	333.3	103
Cancer stomach (151)	12	5.5	219 [†]	39	20.9	187 [†]
Cancer large intestine (153)	10	1.3	121	39	31.3	123
Cancer rectum (154)	2	3.3	60	7	11.7	60
Cancer pancreas (157)	4	6.4	62	17	19.8	85
Cancer resp. system (160-163) ²	33	45.1	72	91	109.3	81 [*]
Cancer prostate (155)	6	4.1	147	45	34.4	142 [*]
Cancer bladder (158)	2	2.5	80	9	12.3	72
Cancer brain, CNS (191-192)	1	35	29	4	5.9	68
Lymphosarcoma (200)	6	2.4	251 [*]	14	6.2	226 [*]
Leukemia (204-207)	11	3.5	315 [†]	16	12.5	128
Diabetes mellitus (250)	13	8.3	157	43	39.0	143 [*]
Ischemic heart ds. (410-413) ³	211	205.9	103	737	741.4	99
Cerebro-vascular ds. (430-438) ⁴	25	10.6	25	182	176.5	103
Arteriosclerosis (440)	4	1.2	223	34	22.1	154 [*]
Chronic resp. disease (490-492)	13	13.6	96	53	56.4	96
Liver cirrhosis (571)	14	11.1	78	35	28.6	122
Accidents poisoning, & violence (except suicide) (E800-999, minus E950-959)	20	34.0	59 [*]	42	66.9	65 [†]
Suicide (E950-959)	10	9.5	105	17	16.7	102
All other causes ⁵	69	94.5	72	289	324.0	89

Deaths expected calculated on basis of 1968 age-specific death rates within U.S. male population.²⁷

1. International Classification of Diseases, Eighth Revision.

2. Approximately 95% of this group are bronchogenic cancer (162.1), within U.S. mortality data.

3. For the age-range 40-49, SMR = 154 (31 deaths).

4. For the age-range 40-54, SMR = 139 (10 deaths).

5. ICD codes 020-136, 240-246, 251-404, 420-429, 441-486, 500-570, 572-795.

* = p < .05; † = p < .01; ‡ = p < .001.

Statistical test used to determine probability, p, was Chi Square test:

$$\chi^2 = \frac{(\text{Observed} - \text{Expected})^2}{\text{Expected}}$$

among steelworkers aged 55 to 64, the 45 to 64 age-range portion of the rubber-worker cohort experienced lower age-specific death rates than the comparison populations. This table indicates that there was no overall mortality excess within this population of rubber-workers during the period 1964 to 1972.

In Table 2, the comparison with-the 1968 US national male population mortality data is presented in more detail. These national data were used as the "standard in the calculation of the number of expected deaths within the cohort. (This calculation makes the assumption that, if the rubber industry is free of life-shortening hazard, then one might expect that the age-specific mortality rates within the national male population would also have applied

within the rubber-worker cohort.)

For each 5-year age-range, the ratio of the actual observed deaths to the expected deaths expresses the age-specific mortality ratio. The age-standardized mortality ratio (SMR) is calculated from the ratio of the total observed deaths for the full age-range to the sum of the age-specific expected deaths for the full age-range. The SMR for the age-range 40-84 was 99.1; for the-active working age-range 40-64 the SMR was 93.2; and for ages 65-84 the SMR was 101.6. Using 1968 Ohio State Mortality data (males) as the standard, the SMRs were very close to the above values — 99.4 for the 40-84 age-range, 94.5 for the 40 to 64 age-range, and 101.8 for the age-range 65-84.

Using the same procedure presented

in Table 2, SMRs were calculated for specific causes of death. The 20 causes of death included in Table 3 account for 84% of all the deaths within the cohort. These 20 categories represent ICD (International Classification of Diseases, Eighth Revision) groupings for underlying cause of death. (Other minor causes of death were also examined but their numbers were generally too small for meaningful analysis.)

Eleven of the cause-specific SMRs show statistically significant deviation from the "expected" figure of 100. It should be noted, however, that since a total of 40 cause-specific SMRs were calculated for Table 3, therefore at the conventional 0.05 level of probability used for making statistical inferences, one would expect 2 of the SMRs to achieve statistical "significance" by chance alone. The highest SMRs were for malignant neoplasms of the stomach and of the lymphatic and haematopoietic systems in each case the SMR was higher for the active age-range (40 to 64) than for the full age-range (40 to 84). For leukemia deaths, the 40 to 64 age-range, the SMR was 315 — i.e. approximately a threefold excess.

Mortality from malignant neoplasms of the large intestine and the prostate was higher than expected. However, malignant neoplasms of the respiratory system and the bladder caused fewer deaths than expected. For deaths from all malignancies, the SMR was slightly elevated (103) for the full age-range. Relatively, it was more elevated for the 40 to 64 age-range — i.e. the all-malignancies SMR (100) was 8% higher than the all-causes SMR (99).

Table 3 also presents the SMRs for eight non-neoplasm causes of death. There was a moderate excess mortality from diabetes mellitus, a slight deficit from chronic respiratory disease (bronchitis, asthma, and emphysema), and some suggestion of excess mortality from liver cirrhosis among the older segment of the cohort. Deaths from accidental and violent causes were significantly below the expected number while deaths from suicide were close to the expected value.

With respect to the cardiovascular system, the number of deaths from arteriosclerosis was considerably higher than expected. (However, this diagnostic category represents a relatively small portion of cardiovascular disease and

suspect as the category into which "thiscellaneous" cardiovascular deaths tend to be lumped. Within the 40 to 64 age-range, mortality from ischemic heart disease was mildly elevated, relative to the all-causes SMR. However, there was a 54% excess of deaths from this cause in the age-range 40 to 44. Similarly, there was a 34% excess of deaths from Cerebrovascular disease in the age-range 40 to 54.

On the assumption that the working environment varies between different rubber plants (because of differences in chemicals and processes used, differences in environmental control procedures, and differences in the local environment), it was decided to compare mortality data from five other smaller rubber manufacturing plants within this same company. These five plants are located in widely differing parts of the U.S. For each plant, mortality data equivalent to that analyzed above in the Akron cohort study was available. However, the populations at risk for each plant were not determined. Table 4 presents results of the proportional mortality analysis, for white males, of the death certificate data from Akron and from these five other plants.

Using 1968 proportional mortality data for white males as the standard, age-standardized proportional mortality ratios (SPMR) were calculated for selected malignant neoplasm deaths. (By comparing with Table 3, it can be seen that the Akron SPMR's afford a good approximation to the respective cause specific Akron SMRs. The theoretic basis for this approximation is discussed elsewhere.²⁰ Note, however, that the SMR was calculated for the total male cohort, with an estimated 14% minority of blacks; whereas the SPMR was calculated for white males only.)

For deaths due to malignant neoplasm of the stomach, the prostate, and the lymphatic and haematopoietic system, the proportional mortality excess at the five other plants was similar to that at the Akron plant. However, for deaths due to malignant neoplasm of the respiratory system, the bladder, and the central nervous system, the SPMR for the five other plants combined was clearly higher overall than for the Akron plant. (The considerable variation in the figures for the individual plants may reflect the small numbers used in the calculations, rather than a true difference in cause-

Table 4. — Age-Standardized Proportional Mortality Ratios (SPMR) for Selected Cancers, White Males, 1964-72, at Various Rubber Manufacturing Plants

Cancer Site (with ICD code)	Age Range	Akron Plant (A)	Other Plants					No. of Deaths	All Plants
			B	C	D	E	F		
Stomach (151)	40-64	2.70	0	1.82	0	3.75	3.33	(15)	2.06
	40-84	1.96	0	1.43	0	1.68	1.25	(40)	1.58
Large bowel (153, 154)	40-64	1.06	0	0.77	1.00	1.00	1.25	(17)	0.93
	40-84	1.91	0.83	0.46	0.91	1.00	0.50	(55)	0.92
Respiratory System (160-163)	40-64	0.72	2.00	1.61	2.04	0.85	0.80	(74)	1.18
	40-84	0.85	1.69	1.53	2.29	0.90	0.62	(152)	1.10
Prostate (185)	40-64	1.30	2.50	1.43	3.75	2.50	0	(9)	1.84
	40-84	1.10	1.43	0.93	1.43	0.87	0.77	(47)	1.09
Bladder (188)	40-64	0	6.57	1.67	3.33	0	0	(5)	1.28
	40-84	0.66	5.00	1.11	2.73	0.91	0	(17)	0.98
Central Nervous System (191, 192)	40-64	0.36	0	1.25	0	3.75	5.00	(6)	0.98
	40-84	0.56	0	1.82	0	3.00	3.33	(9)	0.95
Lymphatic & haematopoietic System (200-209)	40-64	1.76	1.54	2.27	1.11	1.50	0	(26)	1.67
	40-84	1.24	1.58	1.11	1.11	0.94	0	(48)	1.26
Total numbers of all deaths		(1655)	(109)	(265)	(189)	(178)	(74)		(2469)

NOTE: The calculation of the SPMR is exactly analogous to the calculation of the SMR (see Table 2). Where, in the SMR calculation, standard age-specific death rates are applied to the study population's age-specific populations, so, in the SPMR calculation, standard age-specific proportional death rates are applied to the study population's age-specific totals for deaths from all causes.

specific mortality); risks among those smaller plants.)

Discussion

The finding that the death rate from all causes within this cohort of rubber workers was lower than expected, from general population mortality data, needs qualification on two counts. On the one hand, the well-documented socioeconomic class gradient of overall mortality might suggest a higher mortality within a blue-collar population than in the general population. But on the other hand, there is a strong selection process at play, wherein, to be employable in an industrial workforce, an individual must be relatively healthy and active. This selection factor acts to produce a "healthy worker effect", such that, in an industry free of significant life-shortening hazards, death rates within the workforce in question will be less than in the general population. Individuals whose health does not meet the requirements for the specific industry do not enter that industry; those whose health deteriorates below that level do not remain in the in-

dustry. Findings in other industries, free of serious life-threatening hazard, indicate an all-causes SMR of about 80 to 85.^{25, 26}

Clearly, this selection process only directly affects active workers. This is demonstrated in this study by the finding of an SMR of 101 for the post-retirement 65 to 84 age-range, and an SMR of 93 for the 40 to 64 age-range. This latter SMR, by comparison with the abovementioned value of 80 to 85, suggests a small excess mortality among that portion of the rubber worker cohort in the active employment age-range. Assuming that the "healthy worker" selection process also impinges indirectly upon the 65 to 84 age-range, the SMR of 101 suggests some small excess mortality at this age.

The pattern of cause-specific SMR's (Table 3) is, to a moderate extent, consistent with earlier reported mortality data for rubber workers. Deaths within this cohort were excessive for malignant neoplasms of the stomach, large bowel, and the lymphatic and haematopoietic systems, and for certain types of cardiovascular disease in middle age. For

OK social class & leukemia -

cancer is little related to class^{18 30} This gradient could account for a part of the

vous system. This finding gives some support to Mancuso's conclusions — although the OM? plant (Akron) that fell within his study domain showed a marked deficit in this study.

With respect to cardiovascular mortality, overall there was only a slight excess within this cohort. However, there appears to be a considerable increase in risk, for middle-aged rubber workers, of death from ischemic heart disease or cerebro-vascular disease. Such deaths could result from hypertension and/or vascular deterioration occurring in response to exposure to chemicals present in certain work areas. Carbon disulfide and carbon monoxide, for example, have been implicated elsewhere in cardiovascular mortality.^{32 33}

However, until the second phase of this study is completed, and the mortality experience of different groups of rubber workers is compared, it cannot be assumed that the above cause-specific mortality excesses are attributable to work-environment exposure within the rubber industry. Such an excess could be a spurious (secondary) association — perhaps the cohort of rubber workers was a "selected" population with respect to some important etiologic factor (e.g. dietary habits and stomach cancer), or perhaps all persons living in Akron have been exposed to an environmental factor that increases the mortality from some specific cause above that of the general population. However, the supportive proportional mortality findings from the five other plants make this kind of explanation unlikely. But, until it is demonstrated that specific exposures or jobs within the industry are associated with excess deaths, one can only suspect, rather than conclude with confidence, that working in certain jobs within the rubber industry entails an increased risk of dying from specific causes.

Summary

Summary

The population at risk for this historical cohort study comprised hourly (i.e. factory) active and retired employees of a major tire manufacturing plant in Akron, Ohio. Working from pension, payroll, death claims and other company files, a cohort of 6678 male rubber workers, aged 40 to 84 on Jan. 1, 1964, was identified. With few exceptions, this total cohort was followed

for nine years, and data on 1785 deaths was obtained. Comparison with 1960 U.S. national mortality data yielded a Standardized Mortality Ratio (SMR) for all causes of death of 96 for the full cohort, and of 93 for the sub-cohort aged 40 to 64 (the active employment age-range). For specific causes of death the SMR was significantly elevated for malignant neoplasms of the stomach, prostate, and the blood-and-lymph-forming tissues (including leukemia) but was below expected for cancers of the bladder, lung, central nervous system and pancreas. The SMR was significantly elevated for ischemic heart disease in the age-range 40 to 49, and for diabetes mellitus. Analysis of proportional mortality rates among equivalent populations, at five other plants with this same company, indicates a pattern of cancer mortality generally similar to that above — although the rates for malignant neoplasms of the lung, bladder and central nervous system showed a proportional excess. The next phase of this cohort study will compare the mortality experience of workers exposed to different production areas within the plant.

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from malignant neoplasms of pancreas and gall bladder.¹⁰ Some of Mancuso's evidence of excess brain neoplasm deaths in rubber workers^{19 31} refers to "tumors" rather than exclusively to malignant neoplasms. (Because of the relative inaccessibility of the cranial cavity to tissue diagnosis, many death certificates for brain tumor deaths contain no information about the malignant or benign nature of that tumor.) From Table 4 it can be deduced that, in non-Akron plants within the company under study, there has been an almost two-fold proportional excess of deaths due to malignant neoplasm of the central ner-

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