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Mortality Among Rubber Workers

III. Cause-Specific Mortality, 1940-1978

Elizabeth Delzell, S.D., and Richard R. Monson, M.D.

This report describes mortality occurring between 1940 and mid-1978 among 29,087 men and women employed in a rubber plant for at least two years. Mortality patterns for the period July 1, 1974, to July 1, 1978, were compared to previously published findings for January 1, 1940, through June 30, 1974. Expected numbers of deaths were based on U.S. general population mortality data. There were excess deaths from bladder cancer and leukemia among white male union members during both follow-up periods. During recent follow-up of white male union members employed for at least five years, there were excesses in deaths from three additional cancers: esophageal cancer (11 observed/4.8 expected), biliary and liver cancer (6 observed/3.3 expected) and lymphoma and multiple myeloma (14 observed/5.8 expected). Evidence from other studies of rubber workers suggests that observed excesses in deaths from bladder cancer and leukemia are related to workplace exposures. The present findings suggest that occupational exposures etiologically relevant to these diseases may not have been reduced in recent years or that sufficient time has not elapsed for such reductions to result in decreased mortality. Further investigation is required to clarify the contribution of occupational factors to observed excesses in deaths from cancers of the esophagus and the biliary passages and liver and from lymphoma and multiple myeloma.

In 1976, Monson and Nakano² reported the mortality experience of a large group of workers who had worked for five or more years in rubber manufacturing and who were followed from January 1, 1940, through June 30, 1974. Although there was no increase in overall mortality among rubber workers compared to the U.S. general pop-

ulation, there were excess deaths from several cancers. The present study describes mortality through June 30, 1978, among these workers. In addition, men and women employed for two to four years are included in order to determine to what extent their mortality experience resembles that of long-term workers.

Materials and Methods

Study subjects worked at a rubber manufacturing company that has operated in Akron, Ohio, since the late 1800s. The company's personnel records date from 1900 and contain information on name, demographic characteristics and employment dates. Production workers have been members of the United Rubber, Cork, Linoleum and Plastics Workers of America (URW) Union since the late 1930s. URW records on members consist of name, social security number and sequential department changes. Company and URW records were used to enumerate all active and former employees as of July 1, 1971. Detailed descriptions of this procedure have been given elsewhere.^{1,2} Workers who left the company before January 1, 1940, or whose company service dates covered fewer than two full years before July 1, 1971, were not included. Because numbers were small, non-white females and non-white salaried males were also not included. The total number of eligible employees was 29,087, of whom 5,302 had worked for two to four years before July 1, 1971, and were not included in previous studies of these workers.

Five study groups were defined on the basis of employment category (union member or salaried employee), race and sex. Employees were classified as salaried only if they had no record of employment in production jobs. There were 15,613 white male (WM) union members, 1,184 non-white male (NWM) union members, 4,200 female union members, 4,683 salaried males and 3,377 salaried females.

Company censuses in 1974 and 1979 identified 4,470 active employees among the 29,087 study subjects. Exact dates of termination were not obtained for these workers,

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and duration of employment as of the close of the study on July 1, 1978, was estimated as follows. Workers active in 1971 but not in 1974 were assumed to have terminated employment on January 1, 1973, while those active in 1974 but not in 1979 were assumed to have terminated on July 1, 1976. Workers who were active in 1971 or 1974 but who died before the designated termination date were assumed to have left work on the date of death.

Follow-up to ascertain mortality and to measure person-years of observation started on January 1, 1940, or the second anniversary after starting work, whichever was later, and continued to July 1, 1978. The company provided death records for active and pensioned workers, and a Social Security Administration (SSA) search identified deaths among workers not known to be deceased. The company and the SSA reported a total of 9,388 deaths during the period January 1, 1940, through July 1, 1978; 2,533 of these were not included in previously published reports concerning these rubber workers.^{1,2} There were no death, disability or retirement claims or reported earnings for approximately 16% of the 26,232 subjects included in the SSA search. All subjects not known to have died before July 1, 1978, were considered to be alive on that date. Death certificates for 444 (4.7%) of the reported deaths could not be located. The percentage of reported deaths with unavailable certificates varied by employment group (4.0% for WM union members to 9.5% for salaried females), by duration of employment (1.4% for workers employed 15 or more years to 18.6% for those employed two to four years) and by age at death (29% for deaths at and above age 65 to 18.7% for those under 40 years of age at death). Deaths among workers employed two through four years and deaths under age 40 accounted for 11% and 3% of the total deaths, respectively. Decedents for whom a death certificate could not be located were assumed to have died of unknown cause on the date reported; underlying cause of death was coded from available death certificates according to the International Classification of Diseases, 7th Revision.

For each employment group, observed numbers of deaths were compared to numbers expected based on relevant U.S. mortality rates specific for cause, age, calendar time, sex and race. (Cause-specific mortality rates for Ohio are virtually identical to those for the United States; the U.S. rates were used because they are available in greater detail.)

To compute expected numbers, person-years of observation were allocated to five-year age and calendar time categories and multiplied by corresponding U.S. death rates. The resulting quantities were summed over all ages and years to obtain total expected numbers. Ratios of observed to expected numbers of deaths were expressed as standardized mortality ratios (SMRs), which are estimates in percentage form of rate ratios for rubber workers compared to the U.S. general population, adjusted for age and calendar time to the person-years distribution of the employment group of interest. Confidence intervals were derived assuming that observed numbers of death follow a Poisson distribution.³

Mortality patterns for the interval covered in previous reports, January 1, 1940, through June 30, 1974, were compared to those for the period July 1, 1974, through July 1,

1978. These intervals will be referred to as the 1940 through 1974 and the 1974 through 1978 follow-up periods, respectively. Because no new hires after mid-1969 were included in the study, the age distribution or person-years for 1974 through 1978 shifted toward older ages relative to the distribution for 1940 through 1974, and comparisons of SMRs between the two follow-up periods could be misleading for causes of death associated with age. To address this issue, directly age standardized mortality rates were computed for all causes and all cancers for each employment group and follow-up period, using as a common standard the person-years distribution of all employees during the years 1940 through 1978. Also, for comparisons of site-specific cancer mortality in WM union members between the two follow-up periods, age standardized rate ratios were computed using the person-years distribution of men followed during the period 1974 through 1978.

Workers employed for two through four years tended to be younger than those employed for five or more years. To facilitate comparisons of overall mortality between the two duration of employment categories, all-cause death rates were standardized to the person-years age distribution of all employees followed during 1940 through 1978.

Results

There were approximately 441,985 person-years of observation for WM union members, 28,729 for NWM union members, 134,397 for female union members, 770,987 for salaried males and 82,012 for salaried females. Average length of follow-up was 28 years for WM union members, 32 years for union females and 24 years for NWM union members, salaried males and salaried females.

During 1940 through 1978 WM union members experienced excesses in deaths from cancers of the biliary passages and liver (12% excess) and of the bladder (17%) and from leukemia (21%) (Table 1). There were marked deficits in deaths from causes other than cancer and vascular lesions of the central nervous system. Bladder cancer and leukemia mortality were elevated during both follow-up periods. In addition, there were excess deaths from several cancers during 1974 through 1978 only, including cancers of the esophagus, large intestine, biliary system and liver, brain and lymphatic tissues and multiple myeloma. In the lymphatic cancer and multiple myeloma category (ICD codes 200-203), excess mortality was confined to ICD codes 202-203 ("other lymphoma" and multiple myeloma: 16 observed/6.8 expected deaths).

Examination separately of SMRs for men employed two through four years and those employed at least five years showed that with the exceptions of lung cancer and lymphatic cancer and multiple myeloma, cancer excesses occurred only among men who worked for at least five years. Men employed for two through four years experienced slight excesses in lung cancer (16 observed/13.7 expected) and in lymphatic cancer and multiple myeloma (3 observed/1.9 expected) during 1974 through 1978.

Table 2 gives age-standardized rates and rate ratios (RR) for selected cancers among men employed for five or more years. Several patterns for causes of death included in this table are noteworthy:

Table 1. — Mortality Among White Male Union Members According to Cause and Follow-Up Period.

Cause of Death (ICD No.) ¹	Follow-Up Period						
	1940-1974		1974-1978		1940-1978		
	SMR†	Obs‡	SMR	Obs	SMR	Obs	95% CI§
AS causes	86	5694	90	1103	87	6797	85 - 89
Malignant neoplasms (140-205)	94	1093	102	259	96	1352	91 - 101
Digestive organs and peritoneum (150-159)	101	396	113	78	103	474	94 - 113
Esophagus (150)	88	25	191	11	105	36	73 - 145
Stomach (151)	103	98	107	12	103	110	85 - 124
Large intestine (153)	103	115	115	29	105	144	89 - 124
Biliary passages and liver (155, 156)	104	33	179	7	112	40	80 - 152
Pancreas (157)	89	58	64	9	84	67	65 - 107
Lung (162, 163)	91	275	81	67	88	342	79 - 98
Prostate (177)	103	95	101	26	102	121	85 - 118
Bladder (181)	117	49	115	11	117	60	89 - 150
Brain (193)	82	24	147	7	91	31	62 - 130
Lymphatic and multiple myeloma (200-203)¶	94	54	183	22	109	76	86 - 137
Leukemia (204)	122	57	117	11	121	68	94 - 153
Vascular lesions of the central nervous system (330-334)	97	531	83	100	96	631	86 - 114
Diseases of the circulatory system (400-468)	86	2647	78	463	85	3110	82 - 88
Diseases of the respiratory system (470-527)	70	246	88	82	74	328	66 - 82
Diseases of the digestive system (530-587)	52	251	96	43	83	294	74 - 93
Accidents, poisoning and violence (800-996)	64	328	62	32	64	360	57 - 71
Other known causes	61	385	77	63	63	448	
Deaths without certificates 1½ total deaths)	n = 213	3.7%	n = 61	5.5%	n = 274	4.0%	

¹International Classification of Diseases, 7th Revision

†Standardized mortality ratio: 100 x (observed no. of deaths - expected no. of deaths), Expected numbers are based on age-, time-, and cause-specific death rates for U.S. white males

‡Obs - observed number of deaths

§CI - confidence interval of SMR

¶Codes 200, 202 and 203 are not included before 1950

Esophageal cancer rates in WM union members tri- between the two follow-up periods, while rates for white males remained essentially unchanged.

Large intestine cancer rates rose only slightly for WM union members and U.S. white males.

Bladder cancer and leukemia rates among WM members did not change appreciably, nor were e marked trends in these rates for U.S. white males.

4. Other lymphoma and multiple myeloma mortality rates nearly doubled among U.S. white males and quadrupled among WM union members, for whom there was a greater than twofold excess in deaths from these diseases during the period 1974 through 1978.

Further examination of mortality among WM union members who worked for at least five years and died in 1974 through 1978 showed that the observed excesses in

Table 2. — Mortality from Selected Cancers Among White Male Union Members Employed for at Least Five Years, According to Follow-Up Period.

Cause of Death	Follow-Up Period					
	1940-1974			1974-1978		
	Obs*	Rate†	RR‡	Obs	Rate	RR
Esophageal cancer	23	1.3	83	11	38	228
		1.6§			1.7§	
Large intestine cancer	108	8.6	128		9.2	124
		6.7§			7.5§	
Biliary and liver cancer		2.25			2.0	180
		3.8			1.1§	
Bladder cancer	46	2.8§	136	11	38	131
		3.4			2.9§	
Leukemia	57	2.25	152	11	38	136
		1.2			2.85	
Other lymphoma and multiple myeloma¶	18	1.1§	109	14	4.8	242
					2.05	

*Observed number of deaths

†Rate (x 10,000 person-years). Rates for 1940-1974 are adjusted for age according to the distribution of men employed five or more years and followed 1974-1978

‡Ratio (x 100) of standardized rate in rubber workers and standardized rate in U.S. white males

§These numbers are rates (x 10,000 person-years) for U.S. white males, age standardized to the distribution of men employed five or more years and followed 1974-1978

¶Only deaths after 1949 are included

Table 3. — Mortality Among Non-White Male Union Members According to Cause and Follow-up Period.

Cause of Death (ICD No.)	Follow-Up Period							
	1940-1974		1974-1978		1940-1978			
	SMR ¹	Obs	SMR	Obs	SMR	Obs	95% CI	
All causes	65	251	82	72	68	323	61 - 76	
Malignant neoplasms (140-205)	77	45	91	18	80	63	62 - 103	
Digestive organs and peritoneum (150-159)	82	17	121	7	90	24	58 - 135	
Esophagus (150)	81	3	81	1	81	4	22 - 207	
Stomach (151)	80	5	0	0	66	5	21 - 154	
Large intestine (153)	55	2	155	2	81	4	22 - 209	
Biliary passages and liver (155, 156)	154	3	249	1	170	4	46 - 436	
Pancreas (157)	123	4	272	3	160	7	64 - 331	
Lung (162, 163)	83	13	46	3	72	16	41 - 117	
Bladder (181)	0	0	269	1	56	1	1-311	
Lymphatic and multiple myeloma (200-203)†	148	4	253	2	171	6	62 - 372	
Vascular lesions of the Central nervous system (330-334)	55	22	109	9	65	31	34 - 92	
Diseases of the circulatory system (400-468)	79	106	82	26	80	132	67 - 94	
Diseases of the respiratory system (470-527)	38	8	85	4	46	12	24 - 81	
Diseases of the digestive system (530-587)	28	5	116	5	45	10	21 - 82	
Accidents, poisoning and violence (800-998)	55	28	25	2	51	30	35 - 73	
Other known causes	46	29	19	2	42	31		
Deaths without certificates (% total deaths)	n=8	3.2%	n=6	83%	n=14	4.0%		

¹Expected numbers for SMRs are based on age-, calendar time-, and cause-specific death rates for U.S. non-white males

†Codes 200, 202, and 203 are not included before 1950

esophageal cancer and other lymphoma and myeloma concentrated among men who started working between 1935 and 1950 (esophageal cancer: 7 observed/2.3 expected other lymphoma and multiple myeloma: 7 observed/2.5 expected) and who worked for at least 10 years and died 30 or more years after starting work (esophageal Cancer: 11 observed/3.8 expected; other lymphoma and multiple myeloma: 14 observed/4.7 expected). Preliminary analysis of mortality by work area for all WM union members revealed excesses in other lymphoma and multiple myeloma among men employed for five or more years in

the following divisions (observed deaths/expected deaths based on rates in U.S. white males): aerospace (5/2.6), reclaim (4/0.7), and hose and belt (7/3.0). Esophageal cancer was elevated in men who worked for at least five years in rubber reclaim (5/0.9).

Mortality from all causes among NWM union members (Table 3) was 32% lower than expected during the overall study period. Although mortality from most specific causes was also lower than expected, there were excesses during both follow-up periods in deaths from cancers of the biliary passages and liver, pancreas and lymphatic

Table 4. — Mortality Among Female Union Members According to Cause and Follow-Up Period.

Cause of Death (ICD No.)	Follow-Up Period							
	1940-1974		1974-1978		1940-1978			
	SMR ¹	Obs	SMR	Obs	SMR	Obs	95% CI	
All causes	79	730	85	233	80	963	75 - 85	
Malignant neoplasms (140-205)	82	205	57	36	77	241	68 - 87	
Digestive organs and peritoneum (150-159)	75	52	43	8	69	60	52 - 88	
Stomach (151)	74	8	90	2	77	10	34 - 142	
Large intestine (153)	92	26	36	3	79	29	53 - 114	
Biliary passages and liver (155, 156)	106	8	70	1	100	9	46 - 190	
Pancreas (157)	38	4	0	0	28	4	8 - 73	
Lung (162, 163)	97	16	26	2	75	18	44 - 118	
Breast (170)	84	47	75	9	83	56	62 - 107	
Uterus (171-174)†	99	30	181	7	108	37	76 - 149	
Cervix (171)	152	21	123	2	149	23	95 - 224	
Ovary (172)	129	2	223	5	58	7	23 - 120	
Bladder (181)	102	6	0	0	119	5	38 - 278	
Brain (193)	102	6	223	3	124	9	57 - 236	
Lymphatic and multiple myeloma (200-203)†	88	10	30	1	74	11	37 - 133	
Leukemia (204)	87	7	49	1	79	8	34 - 156	
Vascular lesions of the central nervous system (330-334)	70	69	81	28	73	97	59 - 89	
Diseases of the circulatory system (440-468)	73	250	76	92	74	342	66 - 82	
Diseases of the respiratory system (470-527)	72	23	125	16	87	39	62 - 119	
Diseases of the digestive system (530-587)	74	32	103	10	79	42	57 - 107	
Accidents, poisoning and violence (800-998)	85	88	113	9	65	47	62 - 112	
Other known causes	55	28	65	15	58	81		
Deaths without certificates (% total deaths)	n=47	8.4%	n=27	11.6%	n=74	7.6%		

¹Expected numbers for SMRs are based on age-, calendar time-, and cause-specific death rates for U.S. white females

†Codes 171, 200, 202 and 203 are not included before 1950

Table 5. — Mortality Among Salaried Males According to Cause and Follow-Up Period.

Cause of Death (ICD No.)	Follow-Up Period						
	1940-1974		1974-1978		1940-1978		95% CI
	SMR*	Obs	SMR	Obs	SMR	Obs	
All causes	75	866	69	198	70	1064	65 - 74
Malignant neoplasms (140-205)	77	167	59	35	72	202	63 - 83
Digestive organs and peritoneum (150-159)	72	51	101	16	77	67	60 - 98
Esophagus (150)	76	4	146	2	90	6	33 - 196
Stomach (151)	77	13	39	1	72	14	39 - 121
Large intestine (153)	68	14	105	6	76	20	47 - 118
Biliary passages and liver (155, 156)	18	1	337	3	61	4	16 - 115
Pancreas (157)	73	9	31	1	64	10	31 - 119
Lung (162, 163)	81	48	50	10	73	58	56 - 95
Bladder (181)	120	9	49	1	195	10	50 - 133
Brain (193)	97	6	74	1	93	7	37 - 91
Lymphatic and multiple myeloma (200-203)†	110	13	67	2	101	15	57 - 67
Leukemia (204)	99	9	45	1	88	10	41 - 62
Vascular lesions of the central nervous system (330-334)	75	73	64	15	73	88	55 - 90
Diseases of the circulatory system (440-468)	71	406	66	88	70	494	64 - 76
Diseases of the respiratory system (470-527)	51	33	128	26	69	59	53 - 89
Diseases of the digestive system (530-587)	51	31	25	3	47	34	33 - 66
Accidents, poisoning and violence (800-998)	36	41	39	7	45	48	27 - 45
Other known causes	63	68	61	12	65	80	
Deaths without certificates (% total deaths)	n = 47	5.3%	n = 12	6.1%	n = 59	5.5%	

*Expected numbers for SMRs are based on age-, calendar time-, and cause-specific death rates for U.S. white males

†Codes 200, 202 and 203 are not included before 1950

tissues and multiple myeloma. Lymphosarcoma, reticulo-sarcoma and Hodgkin's disease were responsible for the excess mortality in the lymphatic cancer and multiple myeloma category. There were no leukemia deaths, while two were expected during the overall study period. The 21% excess in digestive cancer deaths for the period 1974 through 1978 was accounted for by cancers of the large intestine, biliary passages and liver and pancreas.

Among female union members (Table 4), there were excesses in deaths from cancer of the cervix, bladder and brain during 1940 through 1978. For most other causes, there were deficits in observed deaths, with SMRs ranging

from 28 for pancreas cancer to 100 for cancer of the biliary passages and liver. Excesses in bladder and brain cancers were based on five and nine observed deaths, respectively. The increase in bladder cancer mortality was seen only in the years 1940 through 1974, while the brain cancer excess occurred only in the years 1974 through 1978. There was no excess mortality from respiratory cancer, even among women who worked for at least 20 years (6 observed/8.8 expected). Excess cervical cancer deaths occurred during both follow-up periods. Further analysis of the cervical cancer deaths showed that elevated mortality was confined to women who were

Table 6. — Mortality Among Salaried Females According to Cause and Follow-up Period.

Cause of Death (ICD No.)	Follow-Up Period						
	1940-1974		1974-1978		1940-1978		95% CI
	SMR*	Obs	SMR	Obs	SMR	Obs	
All causes	75	192	56	49	70	241	62 - 80
Malignant neoplasms (140-205)	89	65	51	13	79	78	62 - 98
Digestive organs and peritoneum (150-159)	106	17	83	5	100	23	63 - 150
Lung (162, 163)	74	4	0	0	45	4	12 - 115
Breast (170)	90	16	100	6	93	22	58 - 140
Uterus (171-174)†	45	4	0	0	47	5	15 - 110
Cervix (171)	20	1	0	0	17	1	0 - 94
Cervix (172)	39	1	0	0	30	1	0 - 168
Bladder (181)	282	2	0	0	200	2	23 - 733
Brain (193)	135	3	0	0	103	3	21 - 300
Lymphatic and multiple myeloma (200-203)†	161	6	78	1	125	7	56 - 287
Leukemia (204)	38	1	0	0	29	1	1 - 162
Vascular lesions of the central nervous system (330-334)	68	15	58	5	65	20	39 - 100
Diseases of the circulatory system (440-468)	61	47	51	16	58	63	45 - 74
Diseases of the respiratory system (470-527)	55	5	26	1	46	6	17 - 100
Diseases of the digestive system (530-587)	66	3	23	1	56	10	27 - 103
Accidents, poisoning and violence (800-998)	62	14	115	6	72	20	44 - 112
Other known causes	49	18	36	3	46	21	
Deaths without certificates (% total deaths)	n = 19	9.9%	n = 4	8.2%	n = 23	9.5%	

*Expected numbers for SMRs are based on age-, calendar time-, and cause-specific death rates for U.S. white females

†Codes 171, 200, 202 and 203 are not included before 1950

Table 7. — Mortality from All Causes and from All Cancers According to Employment Group and Follow-Up Period.

Employment Group	Follow-Up Period					
	1940-1974			1974-1978		
	Obs	Crude Rate*	Standardized Rate†	Obs	Crude Rate*	Standardized Rate
white male union members						
All causes	5694	14.1	13.8 (0.2)‡	1103	29.1	13.8 (0.6)
All cancers	1093	2.7	2.6 (0.1)	259	6.8	3.2 (0.3)
Non-white male union members						
All causes	251	10.0	14.7 (1.0)	72	20.1	15.7 (2.0)
All cancers	44	1.7	2.5 (0.4)	19	5.3	3.8 (0.8)
Female union members						
All causes	730	6.0	6.7 (0.3)	233	17.9	6.1 (0.5)
All cancers	205	1.7	1.8 (0.1)	36	2.7	1.1 (0.2)
Salaried males						
All causes	366	9.0	11.3 (0.4)	198	13.3	10.0 (0.7)
All cancers	167	1.7	2.2 (0.2)	35	2.4	1.8 (0.3)
Salaried females						
All causes	192	2.8	6.5 (0.6)	49	13.9	4.3 (0.6)
All cancers	65	0.9	1.9 (0.3)	13	1.0	1.1 (0.3)

*Crude annual rate (x 1,000 person-years)

†Annual mortality rate (x 1,000 person-years), standardized for age to the person-years distribution of all employees followed 1940-1978

‡Numbers in parentheses are standard errors (x 1,000 person-years) of the standardized rates

employed for at least 15 years (16 observed/6.7 expected), who died 25 or more years after starting work (15 observed/7.6 expected) and who started work before 1940 (16 observed/8.1 expected). The uterine cancer SMR for union females increased from 99 in the period 1940 through 1974 to 181 from 1974 to 1978. This change resulted from a marked decline in age-adjusted uterine cancer death rates for U.S. white females from 5.7 per 10,000 person-years in 1940 through 1974 to 2.9 per 10,000 person-years in 1975 through 1978,⁴ while similarly age-adjusted rates for union females changed only slightly from 5.9 to 5.2 per 10,000 person-years during the same intervals.

Compared to U.S. white males, salaried males (Table 5) experienced no increased mortality during the overall study period. For the period 1974 through 1978 there were excesses in deaths from esophageal and biliary and liver cancer, based on two and three deaths, respectively, and

a 28% increase in deaths from diseases of the respiratory system.

For salaried females (Table 6), there were excesses, based on small numbers, in cancers of the bladder, brain and lymphatic tissue and multiple myeloma. These occurred only during the earlier follow-up period. The deaths from cancer of the lymphatic tissues and multiple myeloma were from Hodgkin's disease (2 observed/1.1 expected) and from other lymphoma and multiple myeloma (4 observed/1.2 expected). In contrast to union females, salaried females experienced a marked deficit in cervical cancer deaths during both follow-up periods.

Table 7 gives all-cause and all-cancer age-adjusted mortality rates for each employment group. NWM union members experienced the highest overall mortality rates during both follow-up periods and the highest cancer mortality rate for the years 1974 through 1978. All-cause and all-cancer mortality rates either increased slightly or

Employment Group/ Duration of Employment (Yrs.)	Obs	Crude Rate*	Standardized Rate†
White male union members			
2-4	730	7.8	13.0 (0.5)‡
≥5	6067	17.4	13.8 (0.2)
Non-white male union members			
2-4	40	6.2	20.9 (6.0)
≥5	284	12.7	14.8 (0.9)
Female union members			
2-4	120	3.3	4.5 (0.4)
≥5	843	8.6	7.1 (0.2)
Salaried males			
2-4	101	3.7	8.8 (1.0)
≥5	963	11.6	11.2 (0.4)
Salaried females			
2-4	50	1.3	3.9 (0.8)

remained unchanged during the two follow-up periods for WM and NWM union members and decreased for female union members and salaried employees. Except for the sharp drop in cancer rates in females, these trends are consistent with patterns observed in the general population. The approximate 40% decline in cancer mortality rates among female rubber workers was not paralleled by a similar decrease in cancer mortality rates for U.S. white females, which fell less steeply from about 2.4 per 1,000 person-years in the period 1940 through 1974 to about 2.2 per 1,000 person-years in 1975 through 1978.⁶ For union females the percentage of reported deaths in which cause of death could not be determined because of missing death certificates was nearly two times higher in the years 1974 through 1978 than from 1940 through 1974. This difference may have contributed to the decline in their cancer SMR (Table 4) and rate between the two follow-up periods. However, cancer SMRs corrected by distributing deaths with missing certificates by cause according to the distribution of certified deaths were 88 for the period 1940 through 1974 and 64 for 1974 through 1978. It is therefore unlikely that failure to locate death certificates completely explains this finding.

Except for WM and NWM union members, workers employed for two to four years experienced lower overall mortality than those employed for at least five years (Table 8). Among WM union members, rates were similar in the two duration of employment categories. NWM union members who worked for two to four years experienced higher overall mortality than men who worked for five or more years, although the magnitude of the standard errors of the rates suggests that this difference is consistent with sampling variability. Numbers of deaths from specific causes among short-term workers were generally insufficient for meaningful analysis. Apparent excesses in deaths from certain cancers among WM union members employed for two to four years were mentioned earlier in this paper.

Discussion

The present study evaluated mortality occurring between January 1, 1940, and July 1, 1978, among 29,087 men and women who worked for at least two years at a large rubber manufacturing facility. These workers have now been observed for an average of 27 years per employee. Before discussing specific findings based on their mortality experience, it is important to note several limitations imposed by the methodology used in the study.

First, SMRs and RRs reported in this study are probably conservative estimates of causal associations, if any, between rubber industry employment and specific diseases. Failure to identify all deaths during the study period, unavailability of death certificates for nearly 5% of the reported deaths and use of the U.S. general population as a comparison group are likely sources of underestimation.

Lack of information on disease determinants other than employment and demographic characteristics constitutes another limitation of the study. Without this information, it is difficult to judge whether observed associations reflect causal links between disease and work-related exposures.

Finally, many cause-specific SMRs were based on small numbers of events and were statistically unstable. Therefore, sampling variability cannot be discounted as an explanation for some of the observed excesses and deficits, especially among employment groups other than the WM union members. For this reason, the remaining discussion will focus on findings in the latter study group.

Reports² concerning mortality during 1940 through 1974 among the rubber workers included in this study noted excess deaths from the following cancers: (1) bladder cancer and leukemia in WM union members; (2) lymphatic cancer and multiple myeloma in NWM union members; (3) cervical cancer, bladder cancer and lymphatic cancer and multiple myeloma in females; and (4) lymphatic cancer and multiple myeloma in salaried males. Among females there was excess cervical cancer only in union members, and excess lymphatic cancer and myeloma occurred only in salaried employees. The results of recent follow-up through mid-1978 suggest several additional findings.

Among WM union members, neither SMRs nor directly standardized rate ratios for bladder cancer and leukemia changed appreciably between the two follow-up periods, indicating that the excesses of these diseases among rubber workers have not diminished in recent years. Several explanations are possible: (1) there have been no reductions in occupational exposures associated with these cancers; (2) sufficient time has not elapsed for such reductions to result in decreased mortality; and (3) persistent differences in nonoccupational risk factors for these malignancies exist between rubber workers and U.S. white males. Several studies have identified smoking as a determinant of bladder cancer.⁷⁻¹⁰ Emphysema and lung cancer are also strongly positively associated with smoking, and mortality from these diseases would be elevated among the rubber workers in this study if they smoked more than the general population. However, WM union members experienced deficits of 14% and 16% in lung cancer and emphysema deaths, respectively, and it is thus unlikely that they smoked more than U.S. white males in general.

WM union members employed for at least five years experienced twofold excesses in deaths from esophageal cancer and from other lymphoma and multiple myeloma and an 80% increase in biliary and liver cancer mortality during the period July 1, 1974, through July 1, 1978. Although previous studies of rubber workers noted increased mortality from stomach and large intestine cancer^{11,12,13} and linked these excesses to occupational exposures,^{3,11,14,15} there have been no prior reports of elevated esophageal cancer among rubber industry employees. Alcohol and cigarette consumption are the major known risk factors for this malignancy. However, evidence cited above suggests that rubber workers in this study did not smoke more than the general population, and a similar argument can be advanced against the possibility of higher alcohol consumption among rubber workers: WM union members experienced a 17% deficit in deaths from diseases of the digestive system, and the overall SMR for cirrhosis, which is strongly associated with alcohol intake, was 79.

Mancuso and Brennan¹⁶ suggested that gallbladder

and bile duct cancers are increased among rubber workers. To support this hypothesis, they pointed out that the rubber industry employs numerous hepatotoxic agents and that several nitrosamines chemically related to substances used in rubber manufacturing have been shown experimentally to be liver and biliary carcinogens. Biliary and liver cancer mortality rates among **WM** union members in the present study rose only slightly between the two follow-up periods, and the marked increase in **SMR** seen for the period 1974 through 1978 resulted almost entirely from a sharp decline in rates for U.S. white males after 1969 that was brought about partly by changes in rules for classifying this cause of death." It is possible that procedures for diagnosing, reporting or coding biliary and liver cancer as a cause of death among study decedents differed in some way from those used for general population decedents. Such differences, if present, could account for the excess seen during recent follow-up.

Among the cancers of the hematopoietic and lymphatic tissues, leukemia has been the subject of much investigation in the rubber industry, where exposures to industrial solvents probably produce excess leukemia mortality.²⁰ Our findings and those of other investigators suggest that lymphatic cancers and multiple myeloma may also be elevated in rubber workers. Little is known about the etiology of the various lymphatic cancers and multiple myeloma. Associations have been reported for occupational groups exposed to chemicals,²¹ and to radiation.²²

In conclusion, results of recent follow-up were consistent with mortality patterns previously described for these workers² and for other groups of rubber workers.^{12,13,17,18,26} Compared to their general population counterparts, men and women employed in the rubber industry experience deficits in overall deaths and in deaths from most specific causes but sustain increased mortality from several cancers. Although cancer excesses observed during recent follow-up were based on small numbers and may have occurred by chance or because of systematic differences in nonoccupational risk factors between rubber workers and the general population, the possibility that they are related to industrial exposures should be considered. Currently being examined in detail are associations between specific work areas within the rubber industry and the occurrence of esophageal, biliary and liver, lymphatic and other cancers in order to identify subgroups of workers having high cancer risks. This information will aid in focusing efforts to control workplace exposures to hazardous substances.

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