Mortality among shipyard Coast Guard workers: a retrospective cohort study

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Background: The mortality experience of 4702 (4413 men and 289 women) civilian workers in a US Coast Guard shipyard was evaluated.
Methods: All workers employed at the shipyard between 1 January 1950 and 31 December 1964 were included in the study and were followed through 31 December 2001 for vital status. Detailed shipyard and lifetime work histories found in the shipyard personnel records and job descriptions were evaluated. Workers were classified as likely exposed to any potential hazardous substances. In addition, 20 job groups were created on likely similar exposures. Standardised mortality ratios (SMRs) were calculated based on the general population of the state and adjusted for age, calendar period, sex and race.
Results: The follow-up was successful for 93.3% of the workers. Among all men employed in the shipyard, there was an excess of mortality from all causes of death (SMR 1.08; 95% CI 1.04 to 1.12), respiratory cancers (SMR 1.29; 95% CI 1.15 to 1.43), lung cancer (SMR 1.26; 95% CI 1.12 to 1.41), mesothelioma (SMR 5.07; 95% CI 1.85 to 11.03) and emphysema (SMR 1.44; 95% CI 1.01 to 1.99) and a decrease for cardiovascular diseases (OR 0.95; 95% CI 0.90 to 1.00), vascular lesions of the central nervous system (SMR 0.80; 95% CI 0.67 to 0.96), cirrhosis of the liver (SMR 0.38; 95% CI 0.25 to 0.57) and external causes of death (SMR 0.55; 95% CI 0.44 to 0.68). A similar pattern was observed for the men classified as exposed. No increasing trend of mortality was found with duration of employment in the shipyard, with the exception of mesothelioma (SMRs of 4.23 and 6.27 for <10 years and ≥10 years, respectively). In occupations with at least three cases and with an SMR of ≥1.3, the authors observed a significantly elevated mortality for lung cancer among machinists (SMR 1.60; 95% CI 1.08 to 2.29) and shipfitters, welders and cutters (SMR 1.34; 95% CI 1.07 to 1.65) and for oral and nasopharyngeal cancers among wood workers (SMR 6.20; 95% CI 2.27 to 13.50).
Conclusion: Employment in this Coast Guard shipyard revealed a small but significant excess mortality from all causes, lung cancer and mesothelioma, most of which is probably related to asbestos exposure.

S hipbuilding and repair are highly technical and complex processes, requiring a number of skilled trades and expertise. Ship construction and repair are among the most hazardous industries in the world.[1] Although shipbuilding has been changed radically since 1980 and many exposures have been dramatically reduced, occupational hazards are still present.[2] These include work in confined spaces, work at considerable heights, extensive manual work, and potential exposure to various chemicals (dusts, asbestos, spray mists from paints, coatings, solvents and thinners, metal fumes from welding, burning, soldering and brazing, epoxy resins, lead and chromate paints, oils, greases, etc), and physical hazards (heat and cold, electricity, ionising and non-ionising radiation, noise, vibration, etc). A number of potential exposures typical of shipyard work are known or suspected human carcinogens—for example, asbestos, lead, solvents, polycyclic aromatic hydrocarbons, silica, chromium and cadmium. Specific to shipbuilding and ship repair is that many tasks are often performed within close proximity to workers performing other tasks; therefore, workers may be exposed to, and also experience interactions with, agents not generated from the performance of their particular tasks.[2–5]

The aim of our study of the US Coast Guard shipyard in Baltimore, Maryland is to investigate the long-term mortality experience among civilian workers in relation to work tasks and specific exposures. The US Coast Guard opened this shipyard in 1899 to perform shipbuilding and ship repair and to manufacture and paint sea buoys. The yard expanded shortly after the World War II. Since then, the number of personnel employed has been downsized considerably. Today, the shipyard's 450 workers are mainly engaged in ship repair.

METHODS
Subjects
We abstracted information from personnel records on all civilian workers employed at this US Coast Guard shipyard between 1 January 1950 and 31 December 1964. The cohort was assembled in the late 1970s and workers were enrolled through 1964 to allow at least 15-year latency after initial employment. The total number of workers included in the study was 4758. Individuals with no data on shipyard jobs held (n = 49) and absent or invalid dates of entry or exit from the study (n = 7) were excluded, leaving 4702 for study (4413 men and 289 women). Personnel records were obtained from the Coast Guard shipyard or the St Louis Records Center, a repository of federal government employment records that includes records for workers no longer employed at the shipyard. From the personnel records we obtained name, social security number, date of birth, gender, race, marital status, place of birth, complete work history at the Coast Guard shipyard and jobs held prior to employment at the shipyard.

The cohort was traced through 2001 to determine vital status. Mortality tracing was accomplished using the US Civil Service Retirement System; Social Security Administration and Motor Vehicle Administration records; and since 1979 the National Death Index. For deceased subjects, death certificates were

obtained from the states for deaths before 1979 and underlying and contributing cause of death were obtained from the National Death Index for deaths occurring after 1979. Underlying cause of death was determined using the rules in effect at the time of death and assigned an International Classification of Diseases 9th rubric.

Exposure assessment

All occupations held while a civilian shipyard worker at the Coast Guard yard and all other occupations a subject held prior to Coast Guard employment were coded using the Standard Occupational Codes and Standard Industry Codes.[6 7] We also used specific information on exposures available from the shipyard to group Standard Occupational Codes with likely similar exposures (for example, carpenters, carpenter foremen, and carpenter helpers). For 20 of these job groups there were more than 100 deaths: carpenters; electricians; painters; plumbers; transportation and material moving; vehicle and garage mechanics and repairers; industrial machinery repairers and maintenance; electrical and electronic repairers; other mechanics and repairers; riggers; machinists; sheet metal workers; wood workers; shipfitters, welders, and cutters; freight, stock and material movers; labourers; high level managers; clerical workers; engineers and technicians; and professionals (for example, accountants, managers, purchasing agents, etc). We then classified all shipyard workers in two groups—that is, those exposed to any potentially hazardous substance and those not exposed. We considered exposed workers as those who had ever been engaged in the typical shipbuilding and repair tasks, while non-exposed were those workers who had never been engaged in those jobs (primarily managerial positions and office workers). Over 1000 detailed job descriptions, corresponding to 684 unique jobs, were available dating from 1951 to 1980 from the shipyard to assist in this classification. A total of 30% of the jobs in the work history could be matched directly to a job description. In addition, for about 40% of the jobs there was a close, but not exact, match with an existent job description (for example, there was no job description for a carpenter foreman but there was for a carpenter). Approximately 25% of the remaining jobs without a description were thought to be white-collar jobs, so that exposures were expected to be minimal or nonexistent. The job descriptions typically contained information on tasks performed, location of the job (for example, in shops, on ships, indoors, and out of doors), equipment used (for example, pressure and vacuum measuring apparatus, velocity meters and evaluation, flushing and lead detection equipment), materials used (for example, recharges cooling systems with refrigerant, slices and insulates wire, lubricate parts), and in some cases, data on specific exposures. The latter was usually a general description (most often, fume inhalation, welding flashes and dust). Other sources of information on jobs and exposures at the shipyard included two Coast Guard reports identifying changes, such as the construction of new buildings, changes in procedures, and ventilation controls that took place in the shipyard over time.[8 9] An exposure inventory identifying agents (for example, specific metals, solvents, acids, asbestos and others) on site by job, historical measurement data and two walk-through surveys were conducted by the study industrial hygienist in 1983 and in 2003. We also evaluated duration of employment in shipyard as an exposure metric, using cut point categories of <10 and ≥10 years.

Statistical analysis

Standardised mortality ratios (SMRs) and their 95% confidence intervals (CIs) were calculated based on the general population of Maryland. SMRs were adjusted for age (5-year groups),

calendar period (5-year categories), sex and race. Males and females, whites and blacks were evaluated separately in the total cohort, but women were excluded from further analyses due to the small numbers. Black men were included in the other analyses and were analysed together with white men, but the expected number of deaths was race specific.

We then calculated SMRs by duration of employment (<10 years, ≥10 years) in the shipyard, for all exposed and all unexposed workers (as defined above), and for the 20 job groups with more than 100 deaths. We also calculated the total duration of employment in the shipyard and duration in each of the 20 job groups using cut points categories of <10 and ≥10 years (data not presented).

RESULTS

Vital status follow-up was successful for 4389 (93.3%) of the workers with only 6.7% lost to follow-up. By the end of follow-up (31 December 2001), there were 3331 deaths (table 1). A majority (73.8%) in the cohort were white men, 20.0% were black men, 5.4% were white women, and <1% were black women. Almost 70% of the cohort began their employment at the shipyard between 1950 and 1954. They accounted for 72% of all person-years. Mean age at entry was 35.9 years (median 35 years), mean age at exit from the study was 67.9 years (median 70 years), and mean duration of follow-up was 32.0 years (median 33.8 years). Mean duration of all Coast Guard shipyard jobs was 9.2 years (median 2.9 years), ranging from 0.5 to 43 years. The average number of Coast Guard shipyard jobs per worker was 1.7.

The mortality experience of men and women in the cohort is presented in table 2. Among men, significantly increased mortality was observed for all causes of death (SMR 1.08), all respiratory cancers (SMR 1.29), mesothelioma (SMR 5.07), lung cancers (SMR 1.26) and emphysema (SMR 1.44).

Table 1 Demographic characteristics of the shipyard cohort

Demographic characteristics	Subjects, n (%)	Person-years, n (%)
Ethnicity and sex		
Men	4413 (93.9)	140328 (93.1)
White	3472 (73.8)	109507 (78.0)
Black	941 (20.0)	30821 (22.0)
Women	289 (6.1)	9721 (6.9)
White	252 (5.4)	9080 (6.0)
Black	37 (0.8)	1285 (0.9)
Year entry into study		
1950–4	3276 (69.7)	108436 (72.0)
1955–9	662 (14.1)	20367 (13.5)
1960–4	764 (16.2)	21890 (14.5)
Age at entry (years)		
≤25	822 (17.5)	31856 (21.1)
26–40	2378 (50.6)	82581 (54.8)
41–55	1283 (27.3)	32778 (21.8)
≥56	219 (4.7)	3477 (2.3)
Age at exit		
≤40	154 (3.3)	959 (0.6)
41–55	605 (12.9)	10446 (6.9)
56–70	1713 (36.4)	48993 (32.5)
≥71	2230 (47.4)	90295 (59.9)
Duration of follow-up		
≤30	1959 (41.7)	35675 (23.7)
31–35	539 (11.5)	17572 (11.7)
36–40	644 (13.7)	24255 (16.1)
≥41	1560 (33.2)	73190 (48.6)
Vital status		
Alive	1058 (22.5)	49388 (32.8)
Deceased	3331 (70.8)	97700 (64.8)
Unknown	313 (6.7)	3604 (2.4)
Total	4702 (100)	150693 (100)

Significant deficits among men occurred for all cardiovascular diseases (SMR 0.95) (particularly for vascular lesions of central nervous system: SMR 0.80), cirrhosis of the liver (SMR 0.38), all external causes of death (SMR 0.55), all accidents (SMR 0.53), and motor vehicle accidents (SMR 0.27). Among women no significantly elevated or depressed SMRs were observed (although there was a non-significant excess for respiratory cancers), and no deaths from mesothelioma were recorded.

Among black men (data not presented), significant excesses were observed for prostate cancer (SMR 1.69; 95% CI 1.17 to 2.36) and chronic nephritis (SMR 2.47; 95% CI 1.07 to 4.88). Significantly fewer deaths were found for all circulatory diseases (SMR 0.83; 95% CI 0.73 to 0.95), all vascular lesions of central nervous system (SMR 0.48; 95% CI 0.30 to 0.72), and all external causes of death (SMR 0.49; 95% CI 0.32 to 0.73), in particular all accidents (SMR 0.46; 95% CI 0.25 to 0.77) and motor vehicle accidents (SMR 0.26; 95% CI 0.05 to 0.75). Only 15 deaths occurred among black women (data not presented).

SMRs for duration of employment in the Coast Guard shipyard among men are shown in table 3. Risk of death from mesothelioma increased with duration of employment in shipyard being 4.25 for shorter duration employment (<10 years) and reaching statistical significance of 6.27 for longer employment duration (≥10 years). Risk of all causes of death, all respiratory cancers, laryngeal and lung cancers and respiratory diseases, particularly emphysema, were significantly elevated in the shorter duration category (SMRs of 1.16, 1.35, 2.10, 1.30, 1.23 and 1.67, respectively). Significant deficits

occurred among all shipyard workers in the <10 year duration of employment for cirrhosis of the liver (SMR 0.47), external causes (SMR 0.62), all accidents (SMR 0.60) and motor vehicle accidents (SMR 0.35). The deficits for these causes of death were larger among those employed for 10 or more years.

Among all men (including blacks) classified as exposed, significant excesses occurred for all causes of death combined (SMR 1.08); cancers of the respiratory system (SMR 1.28); mesothelioma (SMR 5.39); and lung (SMR 1.26) (table 4). There were significantly fewer deaths than expected from vascular lesions of central nervous system (SMR 0.80); cirrhosis of the liver (SMR 0.41); all external causes of death (SMR 0.57); all accidents (SMR 0.55); and motor vehicle accidents (SMR 0.26). Among men classified as non-exposed, only prostate cancer had a significantly increased mortality (SMR 2.30) and there was a significant deficit of external causes of death (SMR 0.32). No deaths from mesothelioma were observed among the non-exposed men. Among women, only six were exposed in the shipyard (data not presented). Among non-exposed women, no significantly increased SMRs were found. Due to the small number of women in the study, no further analyses were conducted.

In table 5, we present selected cancer deaths among men by 20 job groups to look for cancer patterns by job and job pattern by cancer. In occupations with at least three cases and with a SMR of ≥1.3, we observed significantly increased risks for oral and nasopharyngeal cancers among wood workers (SMR 6.20) and for lung cancer among machinists (SMR 1.60) and

Table 2 Mortality among shipyard workers: number of observed (Obs) and expected (Exp) deaths and standardised mortality ratios (SMRs)* with 95% confidence intervals, follow-up period to 2001

Cause of death (ICD-9)	Men			Women		
	Obs	Exp	SMR (95% CI)	Obs	Exp	SMR (95% CI)
All causes (001–999)	3210	2974.8	*1.08 (1.04–1.12)*	121	112.0	1.08 (0.90–1.29)
All cancers (140–209)	743	711.2	1.04 (0.97–1.12)	32	30.0	1.07 (0.73–1.51)
Oral and nasopharyngeal (140–149)	18	20.3	0.89 (0.53–1.40)	0	0.4	0.00
Oesophagus (150)	28	26.2	1.07 (0.71–1.55)	1	0.4	2.73 (0.04–15.19)
Stomach (151)	23	26.3	0.88 (0.56–1.31)	0	0.6	0.00
Colon (153, 159)	60	63.9	0.94 (0.72–1.21)	3	3.1	0.96 (0.19–2.79)
Rectum (154)	12	15.0	0.80 (0.41–1.39)	0	0.5	0.00
Liver (155, 156)	9	13.5	0.67 (0.31–1.27)	0	0.5	0.00
Pancreas (157)	27	32.9	0.82 (0.54–1.19)	3	1.4	2.08 (0.42–6.08)
Respiratory system (160–163, 1642–3, 164.8–9, 165)	329	255.6	*1.29 (1.15–1.43)*	11	6.5	1.70 (0.85–3.04)
Mesothelioma (163)	6	1.2	*5.07 (1.85–11.03)*	0	0.04	0.00
Laryngeal (161)	18	11.6	1.56 (0.92–2.46)	1	0.1	8.31 (0.11–46.25)
Lung (162)	305	242.0	*1.26 (1.12–1.41)*	9	6.3	1.43 (0.65–2.71)
Skin (172–173; 187.7, 154.3)	10	10.2	0.98 (0.47–1.80)	1	0.4	2.60 (0.03–14.5)
Breast (174–175)	1	1.1	0.94 (0.01–5.21)	6	5.6	1.07 (0.39–2.32)
Prostate (185)	75	74.0	1.01 (0.80–1.27)	–	–	
Bladder (188)	15	20.3	0.74 (0.41–1.22)	0	0.4	0.00
Kidney (189)	10	14.3	0.70 (0.34–1.29)	0	0.5	0.00
Hodgkin's disease (201)	6	3.6	1.67 (0.61–3.64)	0	0.1	0.00
Multiple myeloma (203.0, 238.6)	13	11.1	1.17 (0.62–2.00)	0	0.5	0.00
Benign neoplasm (201–236; 237.6, 2378–9; 238.0–238.3; 238.8–238.9)	8	9.4	0.85 (0.37–1.67)	0	0.5	0.00
Blood and blood-forming organs (280–289.9)	9	7.7	1.16 (0.53–2.21)	0	0.4	0.00
Mental and psychoneurotic diseases (290–319)	28	30.8	0.91 (0.60–1.32)	4	1.7	2.36 (0.63–1.91)
Cardiovascular diseases (390–459)	1205	1271.0	*0.95 (0.90–1.00)*	42	45.7	0.92 (0.66–1.24)
Arteriosclerotic heart disease (410–414, 429.2)	832	866.1	0.96 (0.90–1.03)	23	26.3	0.88 (0.56–1.31)
Vascular lesions of CNS (430–438)	123	153.0	*0.80 (0.67–0.96)*	9	8.1	1.11 (0.51–2.11)
Respiratory diseases (460–519)	230	209.6	1.10 (0.96–1.25)	4	8.6	0.46 (0.13–1.19)
Emphysema (492)	36	25.1	*1.44 (1.01–1.99)*	1	0.7	1.44 (0.02–8.03)
Cirrhosis of the liver (571.0–571.8)	25	65.0	*0.38 (0.25–0.57)*	0	1.7	0.00
Chronic nephritis (582)	9	5.5	1.65 (0.75–3.13)	0	0.1	0.00
All external causes of death (800–998)	87	157.9	*0.55 (0.44–0.68)*	2	3.9	0.52 (0.06–1.88)
All accidents (800–949)	50	94.0	*0.53 (0.39–0.70)*	2	2.5	0.79 (0.09–2.84)
Motor vehicle accidents (810–829)	10	36.5	*0.27 (0.13–0.50)*	1	1.0	1.02 (0.01–5.68)
Number of person-years	128390			9721		

Bold italic, statistically significant.
CNS, central nervous system.
*Maryland mortality rates.

Table 3 Mortality among men in shipyard: number of observed (Obs) and expected (Exp) deaths and standardised mortality ratios (SMRs)* with 95% confidence intervals by duration of employment in shipyard, follow-up period to 2001

Cause of death (ICD-9)	<10 years			≥10 years		
	Obs	Exp	SMR (95% CI)	Obs	Exp	SMR (95% CI)
All causes (001–999)	1981	1704.4	*1.16 (1.11–1.21)*	1229	1270.4	0.97 (0.91–1.02)
All cancers (140–209)	457	426.3	1.07 (0.98–1.17)	286	284.8	1.00 (0.89–1.13)
Oral and nasopharyngeal (140–149)	8	12.5	0.64 (0.28–1.27)	10	7.8	1.28 (0.61–2.35)
Oesophagus (150)	18	16.9	1.07 (0.63–1.68)	10	9.2	1.08 (0.51–1.99)
Stomach (151)	12	15.4	0.78 (0.40–1.36)	11	10.8	1.02 (0.51–1.82)
Colon (153, 159)	36	37.1	0.97 (0.68–1.34)	24	26.8	0.89 (0.57–1.33)
Rectum (154)	5	8.5	0.59 (0.19–1.37)	7	6.5	1.07 (0.43–2.20)
Liver (155, 156)	6	8.0	0.75 (0.27–1.63)	3	5.5	0.55 (0.11–1.61)
Pancreas (157)	15	19.6	0.76 (0.43–1.26)	12	13.3	0.90 (0.47–1.58)
Respiratory system (160–163, 1642–3, 164.8–9, 165)	211	156.3	*1.35 (1.17–1.54)*	118	99.2	1.19 (0.98–1.42)
Mesothelioma (163)	3	0.7	4.25 (0.85–12.42)	3	0.5	*6.27 (1.26–18.32)*
Laryngeal (161)	15	7.1	*2.10 (1.18–3.47)*	3	4.4	0.68 (0.14–1.98)
Lung (162)	192	148.0	*1.30 (1.12–1.49)*	113	94.0	1.20 (0.99–1.45)
Skin (172–173; 187.7, 154.3)	8	6.2	1.29 (0.56–2.55)	2	4.0	0.50 (0.06–1.79)
Breast (174–175)	0	0.7	0.00	1	0.4	2.48 (0.03–13.80)
Prostate (185)	46	42.6	1.08 (0.79–1.44)	29	31.5	0.92 (0.62–1.32)
Bladder (188)	9	11.1	0.81 (0.37–1.54)	6	9.2	0.65 (0.24–1.42)
Kidney (189)	6	8.6	0.70 (0.26–1.52)	4	5.7	0.70 (0.19–1.80)
Hodgkin's disease (201)	4	2.1	1.88 (0.50–4.80)	2	1.45	1.38 (0.15–4.97)
Multiple myeloma (203.0, 238.6)	9	6.9	1.31 (0.60–2.49)	4	4.2	0.94 (0.25–2.42)
Benign neoplasm (201–236; 237.6, 2378–9; 238.0–238.3; 238.8–238.9)	3	5.4	0.55 (0.11–1.61)	5	4.0	1.26 (0.41–2.94)
Blood and blood-forming organs (280–289.9)	5	4.5	1.10 (0.36–2.58)	4	3.2	1.25 (0.34–3.19)
Mental and psychoneurotic diseases (290–319)	14	19.0	0.74 (0.40–1.24)	14	11.8	1.18 (0.65–1.99)
Cardiovascular diseases (390–459)	718	707.8	1.01 (0.94–1.09)	487	563.2	0.86 (0.95–10.17)
Arteriosclerotic heart disease (410–414, 429.2)	493	477.0	1.03 (0.94–1.13)	339	389.1	*0.87 (0.78–0.97)*
Vascular lesions of CNS (430–438)	75	84.4	0.89 (0.70–1.11)	48	68.6	0.70 (0.52–0.93)
Respiratory diseases (460–519)	143	116.7	*1.23 (1.03–1.44)*	87	92.9	0.94 (0.75–1.16)
Emphysema (492)	22	13.2	*1.67 (1.05–2.53)*	14	11.9	1.18 (0.64–1.98)
Cirrhosis of the liver (571.0–571.8)	19	40.5	*0.47 (0.28–0.73)*	6	24.5	*0.24 (0.09–0.53)*
Chronic nephritis (582)	4	3.2	1.27 (0.34–3.25)	5	2.3	2.16 (0.70–5.04)
All external causes of death (800–998)	62	99.8	*0.62 (0.48–0.80)*	25	58.0	*0.43 (0.28–0.64)*
All accidents (800–949)	35	58.0	*0.60 (0.42–0.84)*	15	35.9	*0.42 (0.23–0.69)*
Motor vehicle accidents (810–829)	8	23.2	*0.35 (015–0.68)*	2	13.3	0.15 (0.02–8.78)
Number of person-years	82543			45847		

Bold italic, statistically significant.
CNS, central nervous system.
*Maryland mortality rates.

shipfitters, welders and cutters (SMR 1.34). An increased mortality from mesothelioma occurred among each of the 20 job groups with an observed mesothelioma death, but none had more than two deaths.

Among non-cancer causes of death the only significant finding was an excess for genitourinary system diseases (OR 2.30) among carpenters (table 6). Increased risks of borderline significance were found for all respiratory diseases among wood workers (OR 1.66; 95% CI 0.96 to 2.69), and for emphysema among labourers (SMR 2.60; 95% CI 0.95 to 5.66). SMRs from arteriosclerotic heart disease and vascular lesions of the central nervous system tended to be less than 1.00 or around 1.00 for most occupations.

We observed only slightly increased mortality risks in job groups with an increase in employment duration, except for gastrointestinal cancers in vehicle and garage mechanics or repairers (SMRs 0.75; 95% CI 0.01 to 149, and 11.81; 95% CI 3.18 to 30.25 for <10 years and ≥10 years, respectively) (data not presented).

DISCUSSION
This study found excess mortality from all causes of death, respiratory cancers, lung cancer, mesothelioma, and emphysema among men employed at the Coast Guard shipyard. Mesothelioma occurred only among men classified as exposed, but mortality from respiratory cancer and lung cancer was similar among the exposed and unexposed. Unexposed male workers, both whites and blacks, however, had a significant

excess of prostate cancer. The number of deaths among women was small (n = 121), and although no women died from mesothelioma, they did experience non-significant excesses similar to men for death from all causes, respiratory and lung cancers, and, in addition, slightly increased mortality from cardiovascular diseases.

The observation of a fivefold excess mortality from mesothelioma in men employed in the Coast Guard shipyard is in agreement with the findings from many other studies that reported a significant excess of mortality from mesothelioma.[4] [10–18] There is little doubt that these findings are attributable to asbestos exposure.[19] [20] No deaths from mesothelioma occurred among men classified as not exposed to potentially hazardous substances. For all Coast Guard shipyard workers, the SMR associated with longer (≥10 years) duration of employment was larger than with shorter duration (<10 years), but numbers were small. Increased risks for mesothelioma were observed for many occupational groups (carpenters; electricians; plumbers; vehicle and garage mechanists; machinists; sheet metal workers; wood workers, shipfitters, welders, cutters; and labourers), indicating that asbestos exposure was probably widespread, which has been noted in shipyards by others.[3] Although pipefitters, welders, sheet metal workers and painters generally have been reported to have the heaviest exposures, exposure to asbestos is associated with many other shipbuilding and repair jobs, because many workers performed their tasks in confined spaces or within close proximity of workers performing asbestos-related tasks.[1] [3]

Table 4 Mortality among men exposed and non-exposed to potentially hazardous substances in the shipyard: number of observed (Obs) and expected (Exp) deaths and standardised mortality ratios (SMRs)* with 95% confidence intervals, follow-up period to 2001

Cause of death (ICD-9)	Exposed in shipyard			Non-exposed in shipyard		
	Obs	Exp	SMR (95% CI)	Obs	Exp	SMR (95% CI)
All causes (001–999)	3038	2804.6	*1.08 (1.05–1.12)*	172	170.3	1.01 (0.86–1.17)
All cancers (140–209)	690	669.4	1.03 (0.96–1.11)	53	41.8	1.27 (0.95–1.66)
Oral and nasopharyngeal (140–149)	18	19.1	0.94 (0.56–1.49)	0	1.2	0.00
Oesophagus (150)	28	24.6	1.14 (0.76–1.65)	0	1.6	0.00
Stomach (151)	22	24.8	0.89 (0.56–1.34)	1	1.5	0.68 (0.01–3.80)
Colon (153, 159)	54	60.2	0.90 (0.67–1.17)	6	3.8	1.60 (0.58–3.49)
Rectum (154)	12	14.2	0.85 (0.44–1.48)	0	0.9	0.00
Liver (155, 156)	9	12.7	0.71 (0.32–1.35)	0	0.8	0.00
Pancreas (157)	24	31.0	0.77 (0.50–1.15)	3	1.9	1.56 (0.31–4.5)
Respiratory system (160–163, 1642–3, 164.8–9, 165)	308	240.4	*1.28 (1.14–1.43)*	21	15.1	1.39 (0.86–2.12)
Mesothelioma (163)	6	1.1	*5.39 (1.97–11.74)*	0	0.1	0.00
Laryngeal (161)	16	10.9	1.47 (0.84–2.39)	2	0.7	2.92 (0.33–10.55)
Lung (162)	286	227.6	*1.26 (1.11–1.41)*	19	14.3	1.33 (0.80–2.07)
Skin (172–173; 187.7, 154.3)	10	9.6	1.04 (0.50–1.92)	0	0.6	0.00
Breast (174–175)	1	1.0	1.00 (0.01–5.54)	0	0.1	0.00
Prostate (185)	65	69.7	0.93 (0.72–1.19)	*10*	*4.4*	*2.30 (1.10–4.22)*
Bladder (188)	15	19.1	0.78 (0.44–1.29)	0	1.2	0.00
Kidney (189)	10	13.4	0.74 (0.36–1.37)	0	0.9	0.00
Hodgkin's disease (201)	6	3.4	1.77 (0.65–3.86)	0	0.2	0.00
Multiple myeloma (203.0, 238.6)	11	10.4	1.05 (0.53–1.88)	2	0.7	3.08 (0.35–11.10)
Benign neoplasm (201–236; 237.6, 2378–9; 238.0–238.3; 238.8–238.9)	8	8.9	0.90 (0.39–1.78)	0	0.6	0.00
Blood and blood-forming organs (280–289.9)	8	7.3	1.10 (0.5–2.2)	1	0.5	2.21 (0.03–12.31)
Mental and psychoneurotic diseases (290–319)	27	28.9	0.93 (0.62–1.36)	1	1.9	0.53 (0.01–2.94)
Cardiovascular diseases (390–459)	1146	1198.2	0.96 (0.90–1.01)	59	72.9	0.81 (0.62–1.04)
Arteriosclerotic heart disease (410–414, 429.2)	793	816.9	0.97 (0.90–1.04)	39	49.2	0.79 (0.56–1.08)
Vascular lesions of CNS (430–438)	116	144.2	*0.80 (0.66–0.96)*	7	8.8	0.79 (0.32–1.64)
Respiratory diseases (460–519)	218	197.3	1.11 (0.96–1.26)	12	12.3	0.97 (0.50–1.79)
Emphysema (492)	34	23.7	1.44 (0.99–2.01)	2	1.4	1.44 (0.16–5.21)
Cirrhosis of the liver (571.0–571.8)	25	61.3	*0.41 (0.26–0.60)*	0	3.7	0.00
Chronic nephritis (582)	8	5.2	1.55 (0.67–3.05)	1	0.3	3.42 (0.04–19.04)
All external causes of death (800–998)	84	148.6	*0.57 (0.45–0.70)*	3	9.3	*0.32 (0.06–0.94)*
All accidents (800–949)	49	88.5	*0.55 (0.41–0.73)*	1	5.53	0.18 (0.00–1.01)
Motor vehicle accidents (810–829)	9	34.3	*0.26 (0.12–0.50)*	1	2.2	0.46 (0.01–2.56)
Number of person-years	120619			7771		

Bold italic, statistically significant.
CNS, central nervous system.
*Maryland mortality rates.

Table 5 Mortality from selected cancer causes among men by ever being employed in various occupational groups (n>100 subjects): number of observed deaths (Obs) and standardised mortality ratios (SMRs)* with 95% confidence intervals, follow-up period to 2001

Occupational groups (number of persons)	Oral and naso-pharyngeal cancers		Laryngeal cancers		Lung cancers		Mesothelioma	
	Obs	SMR	Obs	SMR	Obs	SMR	Obs	SMR
Carpenters (420)	3	1.53 (0.31–4.48)	0		26	1.07 (0.70–1.57)	1	7.59 (0.10–42.25)
Electricians (526)	1	0.47 (0.01–2.63)	1	0.84 (0.01–4.68)	33	1.25 (0.86–1.75)	2	*14.53 (1.63–52.47)*
Painters (214)	0		1	1.72 (0.02–9.59)	16	1.37 (0.78–2.23)	0	
Plumbers(448)	1	0.48 (0.01–2.64)	1	0.84 (0.01–4.65)	28	1.13 (0.75–1.64)	1	8.26 (0.11–45.95)
Transportation & material moving (178)	0		2	3.68 (0.41–13.30)	14	1.31 (0.72–2.20)	0	
Vehicle & garage mechanics or repairers (141)	0		0		9	1.15 (0.52–2.18)	1	24.57 (0.32–136.72)
Ind machinery repairers or maintenance (117)	0		0		7	0.99 (0.40–2.03)	0	
Electrical or electronic repairers (199)	1	1.24 (0.02–6.92)	0		10	1.00 (0.48–1.85)	0	
Other mechanics & repairers (127)	0		1	2.98 (0.04–16.60)	9	1.24 (0.57–2.36)	0	
Riggers (171)	0		0		10	1.06 (0.51–1.95)	0	
Machinists (metal & plastic) (353)	3	2.06 (0.41–6.02)	1	1.22 (0.02–6.81)	*30*	*1.60 (1.08–2.29)*	1	9.72 (0.13–54.09)
Sheet metal workers (395)	2	1.13 (0.13–4.08)	3	3.02 (0.61–8.82)	26	1.15 (0.75–1.69)	*2*	*16.65 (1.87–60.12)*
Woodworkers (214)	*6*	*6.20 (2.27–13.50)*	1	1.81 (0.02–10.07)	13	1.12 (0.59–1.91)	1	18.78 (0.25–104.49)
Shipfitters, welders, cutters, (184)	5	0.94 (0.30–2.18)	7	2.27 (0.91–4.69)	*85*	*1.34 (1.07–1.65)*	1	3.32 (0.04–18.48)
Freight, stock & material moving (114)	0		0		5	0.67 (0.21–1.55)	0	
Labourers (491)	2	0.75 (0.08–2.71)	3	1.93 (0.39–5.65)	28	1.01 (0.67–1.46)	1	9.35 (0.12–52.00)
High level managers (eg, superintendents, managers) (85)	1	2.75 (0.04–15.31)	0	0.00	3	0.61 (0.12–1.79)	0	
Clerical (244)	0	0.00	1	1.63 (0.02–9.06)	10	0.73 (0.35–1.34)	0	0.00
Engineers or Technicians (108)	0	0.00	0	0.00	9	1.61 (0.73–3.05)	0	0.00
Professionals (107)	1	2.04 (0.03–11.33)	0	0.00	5	0.80 (0.26–1.86)	0	0.00

Bold italic, statistically significant.
*Maryland mortality rates.

Table 6 Mortality from selected non-cancer causes among men by ever being employed in various occupational groups (n>100 subjects): number of observed deaths (Obs) and standardised mortality ratios (SMRs)* with 95% confidence intervals, follow-up period to 2001

Occupational groups (number of persons)	Arteriosclerotic heart diseases		Vascular lesions of CNS		All respiratory diseases		Emphysema		All genitourinary diseases	
	Obs	SMR	Obs	SMR	Obs	SMR	Obs	SMR	Obs	SMR
Carpenters (420)	95	0.88 (0.71–1.07)	13	0.70 (0.37–1.20)	20	0.78 (0.48–1.21)	2	0.58 (0.07–1.21)	**12**	**2.30 (1.18–4.01)**
Electricians (526)	94	0.99 (0.80–1.21)	9	0.57 (0.26–1.08)	22	0.97 (0.61–1.47)	2	0.71 (0.08–2.57)	6	1.27 (0.46–2.75)
Painters (214)	47	1.04 (0.77–1.39)	7	0.86 (0.63–2.03)	13	1.19 (0.63–2.03)	3	2.25 (0.45–6.58)	3	1.19 (0.24–3.47)
Plumbers (448)	97	1.08 (0.88–1.32)	15	0.95 (0.53–1.56)	21	0.98 (0.61–1.49)	5	1.89 (0.61–4.42)	0	
Transportation & material moving (178)	37	0.91 (0.64–1.26)	6	0.78 (0.29–1.70)	7	0.73 (0.29–1.50)	2	1.75 (0.20–6.32)	3	1.22 (0.24–3.55)
Vehicle & garage mechanics or repairers (141)	25	0.91 (0.59–1.35)	3	0.69 (0.14–2.01)	6	0.94 (0.34–2.06)	1	1.20 (0.02–6.68)	1	0.80 (0.01–4.42)
Ind. machinery repairers or maintenance (117)	23	0.82 (0.52–1.23)	5	1.01 (0.33–2.37)	5	0.74 (0.24–1.72)	0		1	0.69 (0.01–3.82)
Electrical or electronic repairers (199)	26	0.87 (0.57–1.27)	9	1.77 (0.81–3.37)	9	1.19 (0.54–2.25)	2	2.48 (0.28–8.94)	0	
Other mechanics & repairers (127)	31	1.03 (0.70–1.46)	5	1.00 (0.32–2.33)	3	0.45 (0.09–1.31)	0		0	
Riggers (171)	28	0.88 (0.59–1.28)	5	0.83 (0.27–1.94)	4	0.54 (0.15–1.39)	0		2	1.02 (0.11–3.69)
Machinists (metal & plastic) (353)	68	0.93 (0.72–1.18)	9	0.78 (0.36–1.48)	22	1.32 (0.82–1.99)	5	2.14 (0.69–5.00)	2	0.63 (0.07–2.29)
Sheet metal workers (395)	86	1.04 (0.83–1.28)	9	0.66 (0.30–1.26)	19	0.95 (0.57–1.48)	2	0.80 (0.09–2.89)	2	0.50 (0.06–1.79)
Woodworkers (214)	35	0.89 (0.62–1.23)	4	0.57 (0.15–1.46)	16	1.66 (0.96–2.69)	2	1.85 (0.21–6.69)	3	1.28 (0.26–3.75)
Shipfitters, welders, cutters, (184)	195	0.90 (0.78–1.03)	39	0.99 (0.70–1.35)	67	1.23 (0.96–1.57)	8	1.32 (0.57–2.60)	11	0.86 (0.43–1.54)
Freight, stock & material moving workers (114)	19	0.81 (0.49–1.26)	7	1.54 (0.62–3.18)	9	1.50 (0.68–2.84)	1	1.62 (0.02–9.00)	4	2.54 (0.68–6.50)
Labourers (491)	92	1.01 (0.81–1.24)	10	0.51 (0.25–0.95)	22	0.98 (0.61–1.48)	6	2.60 (0.95–5.66)	6	2.60 (0.95–5.66)
High level managers (85)	12	0.77 (0.40–1.34)	0	0.00	6	1.48 (0.54–3.22)	2	4.55 (0.51–16.45)	0	0.00
Clerical (244)	53	1.14 (0.86–1.49)	4	0.53 (0.14–1.35)	13	1.12 (0.60–1.92)	4	2.97 (0.80–7.61)	2	0.86 (0.10–3.09)
Engineers or technicians (108)	14	0.70 (0.38–1.17)	5	1.56 (0.50–3.64)	5	1.01 (0.33–2.35)	0	0.00	0	0.00
Professionals (107)	15	0.71 (0.40–1.17)	3	0.87 (0.17–2.54)	4	0.76 (0.20–1.94)	1	1.62 (0.02–9.02)	1	0.96 (0.01–5.36)

Bold italic, statistically significant.
CNS, central nervous system.
*Maryland mortality rates.

In the late 1970s the use of asbestos was largely abandoned. Since then, workers in the Coast Guard shipyard have been engaged only in repair work, which is still likely to result in substantial levels of exposures at times.

The excess mortality from lung and laryngeal cancers in our shipyard workers is consistent with many earlier studies.[10–13 15 21–27] Widespread exposure to asbestos was likely a major contributor to these excesses.[13] Unexpectedly, the excesses of risks for lung and laryngeal cancers among men in the shipyard were observed in shorter employment duration categories. The excesses seen among the workers with shorter employment duration could be the result of more intense exposures, or differences in lifestyle factors.

Exposures to possible or known carcinogens other than asbestos occur in a shipyard and could be involved in the lung cancer excess. Lead was often used in marine paints to provide corrosion resistance or to enhance drying.[28] During the grinding, burning and chipping of paint significant exposure to airborne lead can occur.[3 29] Chromium was another heavy metal contained in the paints used at the shipyard, and cadmium may also have been used in the paint. In previous studies welders have been associated with lung cancer, possibly from exposures such as asbestos, chromium, nickel or lead.[15 16 24 30–32] Diesel exhaust also has been associated with lung cancer and could possibly play a role for the small excess seen among the transportation workers.[33–35]

It is interesting that an excess of lung cancer occurred among the unexposed as well as the exposed workers. This could reflect a more widespread exposure to occupational carcinogens at the shipyard than we had anticipated, or to the influence of smoking. We lacked information on smoking, the predominant risk factor for lung cancer. Although the cohort experienced a slight excess mortality from emphysema, no excesses occurred for other tobacco-related diseases—that is, oral and nasopharyngeal cancer (SMR 0.89), stomach cancer (OR 0.88), pancreatic cancer (OR 0.82), bladder cancer (OR 0.74) and arteriosclerosis heart disease (OR 0.96). On balance, therefore, it does not appear that differences in tobacco use are likely to explain the lung cancer excess.

An interesting finding was a significant excess of mortality for oral and nasopharyngeal cancers among woodworkers, and a non-significantly increased risk among machinists and carpenters. Nasopharyngeal cancer has previously been observed among woodworkers in some studies,[36–39] but not in others.[40] Workers in these studies were exposed to wood dust and possibly other dusts, asbestos and various chemicals that were applied to the wood, including pesticides and phenols.[36 41] These Coast Guard shipyard woodworkers and carpenters primarily worked with softwood, although hardwood was used as well. Fewer epidemiological data exist for oral cancer, and it has been suggested that occupational factors play a limited role in its development.[42]

Among the Coast Guard shipyard carpenters a significantly increased mortality was also observed for all genitourinary diseases, a finding that is difficult to interpret. For non-malignant renal diseases, solvents, glues and paints, which may be used by carpenters, as well as dusts, could be the risk factors.[43–45]

Laryngeal cancer is related to alcohol and tobacco use and to asbestos exposure as an occupational risk.[46–48] It has also been associated with silica and other dusts and particulates.[49] The non-significant excess mortality of laryngeal cancer recorded in our study has been reported in other studies in shipyard workers as well,[15 16 24 47] but not in all.[4 22] At the Coast Guard

shipyard the laryngeal cancer excess occurred in most of the 20 job groups, suggesting that if it is the result of occupational exposures, the exposure is relatively widespread. Because asbestos was increased in these same groups, the laryngeal excess could be from asbestos exposure.

An excess of mortality from all non-malignant respiratory diseases approached statistical significance in woodworkers, and shipfitters, welders and material moving workers. A mortality study from the shipyard in Italy found significantly increased SMRs for respiratory diseases, particularly for ship demolishers, masons, smiths, shipwrights, ironsmiths, joiners and carpenters.[4] Respiratory diseases were also reported as prevalent in California shipyards.[50] Although asbestosis is a well-documented health effect in workers exposed to asbestos,[51] we observed only one death in the cohort. This is probably due to the fact that asbestosis is not often mentioned as a leading cause of death on death certificates.

We observed a significant excess in mortality for emphysema among all male shipyard workers and a non-significant excess among exposed male workers. In several specific occupations, such as in painters; plumbers; machinists; shipfitters, welders and cutters; and labourers, a non-significantly increased mortality from emphysema was also observed. Dust and gas exposures may induce oxidative stress, cause destruction of alveolar walls in terminal bronchioles, and lead to emphysema.[52] [53] Silica may cause pulmonary emphysema in addition to silicosis,[54] and a recent study found an association between heavy asbestos exposure and asbestosis with emphysema.[55] Tobacco use, of course, could also explain the emphysema rates.

In this study we observed reduced mortality for stomach cancer in all workers and in exposed workers. A similar inverse risk was found among workers by some investigators in some shipyards and shipyard occupations,[11] [13] [14] [24] [26] whereas others have reported non-significantly increased risks for stomach cancer.[4] [15] [16] Occupational exposures that have been linked to stomach cancer include various dusts, such as mineral, metal and wood dust, and asbestos exposure, although it has been suggested that workplace exposure has a minor role in the aetiology of stomach cancer.[56] [57]

Reduced mortality from all cardiovascular diseases and particularly from vascular lesions of central nervous system was observed among all male shipyard workers, as well as among exposed male shipyard workers. This finding is in agreement with the study in the shipyard in Italy,[4] in which reduced mortality from cardiovascular diseases was reported (SMR 87; 95% CI 81 to 94), while Kurumatani et al[26] found a non-significant excess in mortality from heart disease (SMR 1.49; 95% CI 0.74 to 2.86). Reduced mortality could be explained by the "healthy worker effect",[58] since we used the Maryland male population as the referent. However, the healthy worker effect tends to dissipate with the passage of time and this cohort has been followed for over 30 years.

Among all men in the Coast Guard shipyard, as well as among exposed workers, we observed reduced mortality for cirrhosis of the liver. The study among shipyard workers in Italy found the opposite—a significant excess of mortality (SMR 149; 95% CI 121 to 180).[4] Increased mortality from cirrhosis of the liver was also found in the study of the US Coast Guard marine inspectors, who are exposed to chemicals during the inspection of merchant vessels (SMR 136; 95% CI 79 to 217).[59]

We observed a rather striking deficit from all external causes of death, all accidents and motor vehicle accidents both in all male workers and in exposed workers. These deficits occurred among men and women and in exposed and unexposed men. These deficits are surprising because accidents, including fatalities, are not uncommon in the shipyards and are mostly attributable to slips, trips and falls.[60] However, our data did not

Main message

- Shipyard workers experienced increased mortality from all causes combined. Excesses for mesothelioma and lung cancer occurred in many occupations suggesting that exposure to asbestos was widespread.

Policy implication

- Asbestos exposures from past decades have an impact on current day mortality.

allow us to separate work-related accidental fatalities from non-work accidents.

This study is characterised by both a long follow-up (median duration of follow-up was 34 years) and job histories regarding shipyard employment. The percentage of untraced workers was a little larger than preferred in such studies, but quite well within an acceptable tracing success rate when some of the tracing had to be done before the use of the National Death Index (before 1979).

In this study, we used local Maryland rates to calculate SMRs, as we thought that they would be more representative of the population from which this cohort arose than the total US population. When compared to the US rates, SMRs based on Maryland rates were somewhat lower, but no significant difference was observed. For mesothelioma, all SMRs were almost the same based on either the US or Maryland rates.

In summary, this study indicates that employment in this Coast Guard shipyard revealed a small but significant excess mortality from all causes, lung cancer, mesothelioma and emphysema. Increased mortality from the same causes of death was also observed in workers engaged in typical shipyard jobs, and probably was related to, at least in part, asbestos exposure. Although the use of asbestos was banned in the early 1970s, exposure may have occurred in this cohort during repair of asbestos-containing ships. The major limitation of this study is the lack of information on tobacco use. However, it is unlikely that differences in tobacco use accounted for the findings observed because most of the tobacco-related diseases were not elevated and many studies have found that tobacco seldom confounds occupational analyses.[61–63] The striking deficit from accidents and external causes of death may be a reflection of the personal characteristics of workers in the cohort and/or the safety programme at the shipyard.

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