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Cause-specific mortality and cancer incidence among 28 300 Royal Norwegian Navy servicemen followed for more than 50 years

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Objectives The aim of this study was to examine mortality and cancer incidence in a cohort of 28 300 military servicemen known, from personnel files, to have served in the Royal Norwegian Navy during 1950–2004.

Methods The cohort was followed from 1951–2007 for mortality and from 1953–2008 for cancer. Standardized mortality ratios (SMR) and incidence ratios (SIR) for cancer were calculated from national rates. Internal comparisons [rate ratios (RR)] were made using Poisson regression.

Results Mortality for all Navy personnel was lower than expected for all causes combined (SMR 0.84) and for most disease groups and violent causes, but not for cancer mortality (SMR 1.02). Vessel crews had consistently higher SMR than land-based personnel, still with rates lower than – or close to – national ones. The relative risk between the two subgroups was in the same direction for mortality from alcohol abuse and non-malignant alcohol-related diseases (RR 1.56) and for the incidence of alcohol-related cancers (RR 1.58) and lung cancer (RR 1.65). An overall small excess in the incidence of all cancers combined for the entire cohort (SIR 1.06) was caused by prostate cancer, malignant melanoma, and non-melanoma skin cancer. An excess of bladder cancer was observed among submariners (SIR 1.53).

Conclusion The low all-cause mortality was in line with a "healthy soldier effect". Navy personnel had a lower-than-expected mortality from accidents and suicide. Alcohol-related diseases were more frequent among vessel crews than among land-based personnel, but largely comparable to the rates among all Norwegian men.

Key terms alcohol; cohort study; military; Navy; submariner; vessel crew; violent death.

The essence of military activity is discipline, violence, force and destruction; military exercise includes simulation of war. Service in the Royal Norwegian Navy involves handling of weaponry, explosives, and potentially dangerous machinery. Studies on foreign military populations still tend to show reduced all-cause mortality. A review by McLaughlin et al (2) found lower standardized mortality rates (SMR) for all-causes [meta-SMR 0.76, 95% confidence interval (95% CI) 0.65–0.89] and cancer mortality (meta-SMR 0.78, 95% CI 0.63–0.98) among deployed military personnel compared to the general population.

On the other hand, the military work environment is shown to have an adverse effect on specific causes of death and cancer incidence. Among United Kingdom servicemen, Darby et al (2) observed an elevated risk of mortality from accidents and violence, whereas there was a lower-than-expected mortality from all causes of death, all neoplasms, and all other known non-violent causes. Specifically for the British Royal Navy, mortality from all neoplasms was almost equal to that of the reference population, but two specific hazards were identified: deaths from mesothelioma and neoplasms and diseases associated with alcohol consumption. Inskip (3) observed an SMR for all-cause mortality of 0.86 among British Royal Navy submariners and concluded that they seemed to be a healthy group. Brazilian Navy servicemen showed increased age-adjusted proportional mortality for liver diseases related to alcohol consumption, other specified diseases of the digestive system, and

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diseases of the nervous system, compared to the reference population (4). In line with these reports, alcohol abuse has been suggested as an occupational hazard of military life (5). In the navy, it could be a result of drinking traditions or the on-board supply of alcoholic beverages—starting in the early days of sail when, eg, naval rum was made available to British Royal Navy personnel following the capture of Jamaica in 1655 (6). Military servicemen in the British Royal Navy have shown a higher alcohol consumption and more frequent binge drinking compared to the general population (5).

Earlier, we presented the incidence of potentially asbestos-related cancers (malignant mesothelioma, and cancers of the lung, larynx, pharynx, stomach, and colorectal cancer) among officers and enlisted military personnel serving in the Royal Norwegian Navy during 1950–2004 (7). The aim of this current study was to investigate cause-specific mortality and incidence of other cancers according to duty station (land-based, all vessels, submarines).

Methods

Study population

A historical cohort of 28 345 officers and enlisted servicemen who served in the Royal Norwegian Navy between 1950 and 2004 was established. The cohort covers all branches of the Navy, inclusive of the Fleet, the Coast Guard and the Coastal Artillery, and is believed to comprise virtually all active military personnel in the Navy during this period (7). Women were not included in our study because they represented only 2.5% of the cohort. Additionally, conscripts in compulsory service that did not achieve an officer´s rank were not included. The inventory during our study period covered 7 naval bases, 70 underground coastal forts, 3–4 fortresses and around 300 vessels. The distribution of personnel according to the highest rank or status achieved during this period was: commissioned officers (42%), non-commissioned officers and petty officers (33%), seamen, able seamen and (other) enlisted personnel (25%). The birth years of the cohort members span the period 1883–1984 with a median of 1953. Distribution of personnel according to duty station and average duration of service is shown in table 1. Individual data on tobacco smoking was available only for a limited number (1500) of cohort members participating in a survey among Navy personnel in active service in 2002 [data from Magerøy et al (8)]. No individual quantitative data was available for alcohol consumption, diet or occupational exposure, which, together with tobacco smoking, would be expected to influence mortality and cancer incidence.

Table 1. Distribution of Navy personnel who served during 1950–2004 according to duty station and corresponding average duration of service

Personnel group (N=28 345)	Proportion of all personnel (%)	Total years of service (average)	Years aboard all vessels (average)	Years in sub-marine (average)
All personnel	100	6.2	1.6	0.3
Land-based personnel	46	4.4	·	·
All vessel crews	54	7.8	3.0	0.5
Surface vessel crews	45	7.2	2.7	·
Submariners	9	10.6	4.4	2.9

Case identification and follow-up

The cohort members were followed for event of death from the date of first entrance into Navy service, but no earlier than 1 January 1951, until date of death, date of emigration, or 31 December 2007, whichever came first. By the end of follow-up, all cohort members were either known to (i) be alive and resident in Norway, (ii) have died, or (iii) have emigrated. Data on residence, vital status and emigration was provided by the National Population Register, which is continuously updated for the whole Norwegian population. We obtained date and underlying cause of deaths by linkage to the cause-of-death registry at Statistics Norway, which eventually receives the death certificates for all deaths in Norway. The linkage was based on 11-digit unique personal identification numbers given to all citizens of Norway alive in 1960 or born later. For those who died before 1960, linkage was based on name and date of birth. Deaths were classified according to the International Classification of Diseases (ICD), 6th revision through 1957, 7th revision during 1958–1968, 8th revision during 1969–1986, 9th revision during 1986–1995, and 10th revision during 1996–2007.

All cohort members were followed for incident cancers from the date of first entrance into Navy service, but no earlier than 1 January 1953, until date of death, date of emigration, or 31 December 2008, whichever came first. Cancer diagnosis and date of diagnosis were obtained by linkage to the Cancer Registry of Norway, which, due to compulsory reporting, is virtually complete (9). Cancer was classified according to ICD, 7th revision, as registered by the Cancer Registry of Norway. More than one cancer diagnosis could be counted for each individual.

The mortality rates are regarded as valid estimates of disease risk across the population at any time as the national public healthcare system provides fairly equal diagnostic services and treatment of severe and chronic diseases to all inhabitants, irrespective of place of residence or socioeconomic status.

Ethics approval

The study was approved by the Norwegian Data Inspectorate, the Regional Ethics Committee and the Norwegian Directorate of Health.

Alcohol-related diseases and cancers

Deaths by alcohol-related diseases other than cancer were defined as caused by "mental and behavioral disorders due to use of alcohol" (ICD-10 code F10) and liver cirrhosis (ICD-10 code K70). Alcohol-related cancers were defined by cancers of (i) the upper-aero digestive tract [which includes tongue (ICD-7 code 141), mouth (ICD-7 codes 143–144), pharynx (ICD-7 codes 145–148), esophagus (ICD-7 code 150) and larynx (ICD-7 code 161), and (ii) the liver (ICD-7 code 155) combined]. This definition was also used by Pukkala et al (10) in a census-based study on occupational cancer risk in the five Nordic countries and by Kjaerheim et al (11, 12) in Norwegian studies of cancer in the restaurant business.

Statistical analysis and duty stations

The analysis was based on a comparison of the observed numbers of deaths or cancer cases with those expected, computed from national five-year age-specific and five-year period-specific rates among all Norwegian men. SMR and standardized incidence ratios (SIR) were calculated; 95% CI were computed on the assumption of a Poisson distribution of the observed events.

Mortality and cancer incidence were presented for the whole cohort and three subsets: personnel who *never* served aboard a vessel (land-based personnel), personnel who *ever* served aboard (vessel crews), and an additional subgroup of vessel crews who *ever* served aboard the submarines (submariners). Personnel within the subsets were followed from the first day of entrance into the Navy (but no earlier than 1 January 1951 for mortality and 1 January 1953 for cancer) as vessel crews normally start their on-board service within the first few weeks of initial service. Duration of service is not included in the analyses as it is generally short (table 1), does not proxy any known occupational exposure, and is expected to be correlated with socioeconomic status such as military rank. Poisson regression analysis was used to compare rates according to duty station, with observation period and age at risk included in the models. Relative risks, expressed as rate ratios (RR), were calculated for vessel crews with reference to land-based personnel. Epicure (Hirosoft International Corp, Seattle, WA, USA) and Stata (StataCorp LP, College Station, TX, USA) software packages were used for statistical analysis. $P<0.05$ indicates statistical significance.

Of total deaths, 78 (2%) were classified as being of an "unknown cause"; of these, 36 occurred during 2000–2007. According to Statistics Norway, most of these deaths probably occurred abroad. The number of Norwegians dying abroad increased by 20% during 2000–2007, and 90% of all deaths abroad in 2007 were of unknown cause (13). Individuals with unknown cause of death were excluded from all SMR and Poisson analyses.

Death within 31 days from the end of last recorded service was regarded as being service-related, but we were not able to discriminate between active- and off-duty deaths.

Results

Total mortality

There were 3648 deaths of known cause during 1951–2007. Average follow-up time was 31.5 years. All-cause mortality was on average 16% lower than expected. The SMR was 0.52 during the 1950s but stable at about 0.85 throughout the last five decades (data not shown). Table 2 shows the mortality from all causes combined and selected causes for the cohort, as a whole and for personnel according to duty station. Mortality rate ratios derived by Poisson regression are shown in table 3, where the risks for vessel crews were compared to land-based personnel. All-cause mortality was lower than expected for vessel crews as well as land-based personnel (table 2), but the Poisson analysis showed a significantly higher mortality among vessel crews when the two groups were compared (RR 1.15) (table 3).

Alcohol-related deaths and cancers

Deaths from alcohol abuse and non-neoplastic alcohol-related diseases were two thirds of that expected for all Norwegian men. Cirrhosis of the liver constituted half the number of these deaths, giving a SMR of 0.73 (35 deaths, 95% CI 0.51–1.02). The incidence of alcohol-related cancer was similar to that of the reference population (table 4). Compared to land-based personnel, vessel crews had 50–60% higher risk of dying from non-malignant alcohol-related diseases and of being diagnosed with an alcohol-related cancer (tables 3 and 6).

Deaths from violent causes

Among all personnel, a lower-than-expected mortality was seen for external causes of injury and poisoning combined (SMR 0.64) and for selected sub-categories in this group: transport accidents (SMR 0.78), other

Table 2. All-cause mortality and selected causes among 28 265 Royal Norwegian Navy servicemen (890 771 person-years) and among personnel according to duty station: land-based personnel (never vessel, 401 493 person-years), all vessel crews (489 278 person-years), and a subgroup of the latter: submariners (86 815 person-years). Follow-up 1951–2007. Standardized mortality ratio (SMR) adjusted for age and time period with 95% confidence intervals (95% CI). [ICD-10= International Classification of Diseases, 10th revision; Obs=observed number of cases; Exp=expected number of cases.]

Causes of death	ICD-10	Personnel group	Obs	Exp	SMR	95% CI
All causes	A00–Y99	All personnel	3648	4339.4	0.84	0.81–0.87
		Land-based	1535	1986.6	0.77	0.73–0.81
		All vessel crews	2113	2352.7	0.90	0.86–0.94
		Submariners	303	354.4	0.85	0.76–0.96
Alcohol abuse and alcohol-related diseases [a]	F10, K70	All personnel	73	108.6	0.67	0.53–0.85
		Land-based	25	48.2	0.52	0.34–0.77
		All vessel crews	48	60.4	0.79	0.58–1.05
		Submariners	4	10.3	0.39	0.11–1.00
Malignant neoplasms	C00–C97	All personnel	1208	1189.6	1.02	0.96–1.07
		Land-based	503	536.2	0.94	0.86–1.02
		All vessel crews	705	653.4	1.08	1.00–1.16
		Submariners	108	100.3	1.08	0.89–1.30
Diseases of the circulatory system	I00–I99	All personnel	1315	1532.4	0.86	0.81–0.91
		Land-based	569	713.6	0.80	0.73–0.87
		All vessel crews	746	818.8	0.91	0.85–0.98
		Submariners	110	114.3	0.96	0.80–1.16
Ischemic heart disease	I20–I25	All personnel	819	951.7	0.86	0.80–0.92
		Land-based	344	438.7	0.78	0.71–0.87
		All vessel crews	475	513.0	0.93	0.85–1.01
		Submariners	67	72.5	0.92	0.72–1.17
Cerebrovascular diseases	I60–I69	All personnel	200	261.3	0.77	0.67–0.88
		Land-based	94	125.9	0.75	0.60–0.91
		All vessel crews	106	135.4	0.78	0.65–0.95
		Submariners	12	18.0	0.67	0.34–1.16
Diseases of the respiratory system	J00–J99	All personnel	170	231.1	0.74	0.63–0.85
		Land-based	71	106.9	0.66	0.52–0.84
		All vessel crews	99	124.2	0.80	0.65–0.97
		Submariners	11	16.7	0.66	0.33–1.18
Diseases of the digestive system	K00–K93	All personnel	108	133.4	0.81	0.67–0.98
		Land-based	46	60.9	0.76	0.55–1.01
		All vessel crews	62	72.5	0.86	0.66–1.10
		Submariners	7	11.1	0.63	0.25–1.29
External causes of injury and poisoning	V01–X59	All personnel	402	628.4	0.64	0.58–0.71
		Land-based	151	282.6	0.53	0.46–0.63
		All vessel crews	251	345.8	0.73	0.64–0.82
		Submariners	39	59.7	0.65	0.46–0.89
Transport accidents	V01–V99	All personnel	155	199.9	0.78	0.66–0.91
		Land-based	54	88.7	0.61	0.46–0.79
		All vessel crews	101	111.3	0.91	0.75–1.10
		Submariners	16	19.5	0.82	0.47–1.33
Other accidents	W00–19, X40–49	All personnel	138	219.2	0.63	0.53–0.74
		Land-based	48	98.9	0.49	0.36–0.65
		All vessel crews	90	120.3	0.75	0.61–0.93
		Submariners	10	20.0	0.50	0.24–0.92
Suicide	X60–84,Y87.0	All personnel	101	189.6	0.53	0.44–0.65
		Land-based	47	86.1	0.55	0.40–0.73
		All vessel crews	54	103.5	0.52	0.39–0.68
		Submariners	12	18.3	0.65	0.34–1.14

[a] Mental and behavioral disorders due to use of alcohol (F10), liver cirrhosis (K70)

Table 3. Mortality rate ratios (RR) comparing vessel crews with land-based personnel in the Royal Norwegian Navy. Poisson regression analysis adjusted for observation period and age with 95% confidence intervals (95% CI). Follow-up 1951–2007. [ICD-10=International Classification of Diseases, 10th revision]

Causes of death	ICD-10	RR	95% CI
All causes	A00–Y99	1.15	1.08–1.23
Alcohol abuse and alcohol-related diseases [a]	F10, K70	1.56	0.96–2.52
Diseases of the circulatory system	I00–I99	1.12	1.00–1.24
Diseases of the respiratory system	J00–J99	1.18	0.86–1.60
Diseases of the digestive system	K00–K93	1.14	0.78–1.67
External causes of injury and poisoning	V01–X59	1.36	1.11–1.66

[a] Mental and behavioral disorders due to use of alcohol (F10), liver cirrhosis (K70)

accidents (SMR 0.63) and suicide (SMR 0.53) (table 2). For injury and poisoning combined, the mortality was lower than expected among both land-based personnel (SMR 0.53) and vessel crews (SMR 0.73), although the Poisson regression analysis confirmed a 36% higher mortality in the latter (table 3). Mortality from transport accidents was significantly lower than expected among land-based personnel, but not convincingly so among vessel crews (table 2). Suicide occurred at nearly half the expected rate for both personnel groups. A total of 206 service-related deaths (ie, deaths within one month after end of last recorded service) were observed, of which 47 were deaths from violent causes. Violent causes counted for 26% and 17% of service-related deaths among vessel crews and land-based personnel, respectively.

Deaths from other causes

The most common cause of death in the cohort was diseases of the circulatory system (1315 cases), which was 14% lower than expected (table 2). Except cancer mortality, which was similar to that of the general population, the mortality from all other selected groups of diseases was lower than expected for the cohort as a whole. The Poisson regression analyses suggested a 10–20% higher risk of death from diseases of the circulatory, respiratory, and digestive system among vessel crews compared with land-based personnel (table 3).

Cancer incidence

There were a total of 3362 cancer cases in the cohort during follow-up. Average follow-up time was 32.2 years. The risk for selected forms of cancer is presented for the cohort as a whole in table 4 and for personnel according to duty station in table 5. Relative risks for vessel crews compared to land-based personnel are presented in table 6. The overall cancer risk among all personnel was slightly elevated, with 179 excess cases. Melanoma of the skin (SIR 1.18), other skin cancers (SIR 1.37), and prostate cancer (SIR 1.12) counted for 88% of the excess number of cases. The total incidence of lung cancer was close to that expected for the general population, although elevated by 21% among vessel crews and lowered by 25% in the land-based personnel group (table 4), a difference confirmed in the Poisson regressions (table 5). Vessel crews also showed a higher incidence of all cancers combined (RR 1.16). Submarine service was associated with an excess of bladder cancer (SIR 1.53). The SIR for prostate cancer was elevated among both vessel crews and land-based personnel.

Discussion

For the cohort as a whole, we found a lower-than-expected all-cause mortality and mortality from most selected causes of death. Cancer incidence was slightly elevated, mainly caused by prostate and skin cancers. In general, vessel crews had higher mortality rates and cancer incidence rates compared to those of land-based personnel, inclusive of deaths from violent causes and deaths from non-malignant alcohol-related diseases, and also a higher incidence of alcohol-related cancers and incidence of lung cancer.

The strengths of this study were the quality and the completeness of the outcome derived from independent sources. There was no loss to follow-up except emigrations at specified dates. Accurate Navy service history (duration, occupation, and workplaces) and unique personal identity numbers secured reliable and unbiased estimates. Weaknesses were a relatively short duration of service in the Navy and a lack of information about other (non-military) occupations. We had no access to individual occupational exposures in the Navy and lacked data on lifestyle for more than a minor part of the cohort (see below).

Total mortality

The low overall mortality is most likely in part a result of selections before and during initial compulsory military service, where individuals are excluded if physically unfit or unable to adjust to military discipline. Further selection occurs for those pursuing a military career, caused by the high mental and physical demands that are part of the life at officer candidate schools and military academies. In addition, officers are required to stay fit during service and pass physical and medical tests at regular intervals. The mortality pattern was in accordance with the "healthy soldier effect", as described in the review by McLaughlin et al (1), but of lesser magnitude. Of the 12 cohorts in the

Table 4. Cancer incidences among 28 345 Royal Norwegian Navy servicemen followed between 1953–2008 (912 527 person-years). Standardized incidence ratio (SIR) adjusted for age and time period with 95% confidence intervals (95% CI). [ICD-7= International Classification of Diseases, 7th revision; Obs=observed number of cases; Exp=expected number of cases.]

Cancer site	ICD-7	Obs	Exp	SIR	95% CI
All sites	140–204	3362	3183.0	1.06	1.02–1.09
Alcohol-related cancers [a]	141, 143–148, 150, 155, 161	147	153.3	0.96	0.82–1.13
Lip	140	14	20.3	0.69	0.38–1.16
Stomach	151	109	113.5	0.96	0.80–1.16
Colon	153	266	258.1	1.03	0.91–1.16
Rectum	154	159	152.8	1.04	0.89–1.22
Pancreas	157	82	78.1	1.05	0.83–1.30
Trachea, bronchus, and lung	162	375	370.5	1.01	0.91–1.12
Prostate	177	777	696.7	1.12	1.04–1.20
Testis	178	117	107.7	1.09	0.91–1.30
Kidney, renal pelvis, and urether	180	116	115.3	1.01	0.84–1.21
Bladder and other urinary organs	181	207	198.2	1.04	0.91–1.20
Melanoma of skin	190	217	183.8	1.18	1.03–1.35
Other skin	191	168	122.9	1.37	1.18–1.59
Brain, nervous system	193	126	122.9	1.03	0.86–1.22
Thyroid gland	194	14	21.4	0.66	0.36–1.10
Lymphomas	200–202	143	143.4	1.00	0.85–1.17
Multiple myeloma and leukemias	203–204	142	137.6	1.03	0.88–1.22

[a] Tongue (141), mouth (143, 144), pharynx (145–148), oesophagus (150), liver (155), larynx (161).

Table 5. Incidence of selected cancers among Royal Norwegian Navy servicemen according to duty station: land-based personnel (411 208 person-years), all vessel crews (501 319 person-years), and a subgroup of the latter: submariners (89 315 person-years). Follow-up 1953–2008. Standardized incidence ratio (SIR) adjusted for age and time period with 95% confidence intervals (95% CI). [ICD-7= International Classification of Diseases, 7th revision; Obs=observed number of cases; Exp=expected number of cases.]

Cancer site	ICD-7	Personnel group	Obs	Exp	SIR	95% CI
All sites	140–204	Land-based	1382	1418.1	0.97	0.92–1.03
		All vessel crews	1980	1764.9	1.12	1.07–1.17
		Submariners	332	288.6	1.15	1.03–1.28
Alcohol-related cancers [a]	141, 143–148, 150, 155, 161	Land-based	50	68.3	0.73	0.54–0.97
		All vessel crews	97	85.0	1.14	0.93–1.39
		Submariners	18	14.1	1.28	0.76–2.02
Trachea, bronchus, and lung	162	Land-based	123	163.0	0.75	0.63–0.90
		All vessel crews	252	207.5	1.21	1.07–1.37
		Submariners	32	33.5	0.95	0.65–1.35
Prostate	177	Land-based	351	308.6	1.14	1.02–1.26
		All vessel crews	426	388.1	1.10	1.00–1.21
		Submariners	69	62.6	1.10	0.86–1.40
Bladder and other urinary organs	181	Land-based	87	87.6	0.99	0.80–1.23
		All vessel crews	120	110.6	1.09	0.91–1.30
		Submariners	27	17.6	1.53	1.01–2.23
Melanoma of skin	190	Land-based	97	82.0	1.18	0.96–1.44
		All vessel crews	120	101.8	1.18	0.99–1.41
		Submariners	24	17.7	1.35	0.87–2.01
Other skin	191	Land-based	67	54.5	1.23	0.95–1.56
		All vessel crews	101	68.4	1.48	1.21–1.79
		Submariners	20	10.8	1.85	1.13–2.86

[a] Tongue (141), mouth (143, 144), pharynx (145–148), oesophagus (150), liver (155), larynx (161).

Table 6. Incidence rate ratios (RR) for selected cancers among vessel crews with reference to land-based personnel in the Royal Norwegian Navy. Poisson regression analysis adjusted for observation period and age with 95% confidence intervals (95% CI). Follow-up 1953–2008. [ICD-7=International Classification of Diseases, 7th revision]

Cancer site	ICD-7	RR	95% CI
All sites	140–204	1.16	1.08–1.24
Alcohol-related cancers [a]	141, 143–148, 150, 155, 161	1.58	1.12–2.22
Lung cancer	162	1.65	1.33–2.04
Non-melanoma skin cancer	191	1.20	0.88–1.63

[a] Tongue (141), mouth (143, 144), pharynx (145–148), oesophagus (150), liver (155), larynx (161).

review, 9 comprised US military personnel, who were trained for offensive warfare around the world and probably subject to even more stringent selection. The magnitude of the "healthy soldier effect" is not only dependent on the mortality in the cohort under study, but also on that of the reference population. The less pronounced "healthy soldier effect" in our Norwegian cohort could possibly be caused by an egalitarian society with an evenly distributed high standard of living and health services provided by the State to all citizens.

Alcohol-related deaths and cancers

The results for alcohol-related deaths and diseases indicate alcohol consumption similar to or lower than that of Norwegian males in general, a finding which is supported by results from surveys in the Norwegian Navy (14). Furthermore, our observation is in line with the results of Pukkala et al (10), where military men in the Nordic countries showed a lower-than-expected mortality from liver diseases (SMR 0.80) and an incidence of alcohol cancers similar to that of non-military men.

The higher risk of alcohol-related diseases among vessel crews compared to land-based personnel could possibly be linked to post-military service in the merchant fleet. An 84% excess of alcohol-related cancers among Norwegian civilian seamen have been observed (10). Our results do indeed contrast the excess alcohol-related mortality reported in the British and Brazilian navies, where a doubling of the risk of alcohol-related death has been reported (2, 4). Interestingly, the rum tradition was abolished in UK as late as 1970 (6, 15), while the Norwegian tradition of distributing rations of distilled spirits aboard navy vessels was abandoned more than 80 years earlier (16).

Deaths from external causes

The death rates of external causes, including transport accidents, other accidents and suicide, were very low. In Finland, the accident frequency for military work was lower than for civilian work (17). In contrast, Darby et al (2) found a SMR of accidents and violence of 1.32 ($P<0.001$) among British Royal Navy personnel compared with the national rates, and Inskip (3) observed a non-significant elevated SMR of accidents and violence of 1.15 among British Royal Navy submariners, mainly caused by transport accidents. Even in our data, we found a difference between vessel crews and land-based personnel. It is reasonable to speculate if this might be due to a higher risk of accidents aboard a vessel compared to land-based activity and the higher consumption of alcohol. Bell et al (18) noted that alcohol use was associated with a 10-fold increase in reckless behavior among male US army soldiers on active duty. Similarly, in a census-based study on mortality among occupational groups in Norway, Borgan (19) reported a higher risk of death by external causes among Norwegian seamen compared to land-based personnel. Anyway, the low death rate from violent causes in our cohort is remarkable for an organization designed for military activity, and it might reflect—in addition to the obvious absence of real warfare—a culture of safety, involving selection of personnel, proper training, regulations, and a psychosocial environment with emphasis on personal control. These factors might even outbalance the possible attraction of risk takers to military jobs.

Deaths from other causes

Navy personnel had a lower-than-expected mortality from circulatory, respiratory, digestive, and infectious diseases. Theoretically, this could have been caused by differences in tobacco smoking, but judged by the lung cancer incidence, it seems fair to assume that the historical smoking habits in the cohort have been compatible with those of the general population. This may suggest that factors other than smoking, such as selection by employment, diet, physical activity, or occupational exposures may have had a positive impact on the incidence and prevalence of these diseases.

Differences across personnel groups explained by tobacco smoking?

A proportion of the difference in mortality and cancer incidence between vessel crews and land-based personnel is likely attributable to a higher prevalence of smoking among vessel crews. An earlier study showed an excess of mesotheliomas in the latter group (20). Based on an estimated ratio of 0.7–1.0 between asbestos-related lung cancer deaths and mesothelioma deaths, suggested from UK data by Darnton et al (21), an estimated 5–8% of the lung cancers among vessel crews could be ascribed to asbestos exposure, leaving about

16–18% to be explained by smoking as the predominant factor. According to self-reported smoking data among 1500 cohort members in active service in 2002, 27% of those who ever served aboard a vessel were present-day smokers, in contrast to 20% of the land-based group [$P<0.005$ for this difference; data from Magerøy et al (8)], in line with a possible historical difference in the same direction. According to Ezzati & Lopez (22), the leading causes of death from smoking in industrialized regions in 2000 were cardiovascular diseases, lung cancer, and chronic obstructive pulmonary disease, and we therefore assume that lower mortality from circulatory and respiratory diseases observed among land-based personnel compared to vessel crews, at least in part, can be explained by less tobacco smoking.

Cancer incidence

Apparently, the modestly elevated incidence of all cancers combined contrasts the low over-all mortality and the general "healthy soldier effect". In this connection, it is important to be aware that cancer incidence is not only a result of exposures and risk factors, but even influenced diagnostic pressure, such as screening activities and improved medical diagnostics. The steep increase in prostate cancer incidence seen in Norway since 1990 has been attributed to the increasing use of prostate-specific antigen (PSA) tests among asymptomatic men (23, 24). A plausible explanation of our finding of an elevated incidence of prostate cancer is a difference in diagnostic intensity compared to the reference population, possibly taking place in regular health examinations among active or retired personnel. In line with this assumption, Zhu et al (25) regarded screening as a likely explanation to the doubled incidence seen among US military men. Interestingly, Darby et al (2) found a 56% increased prostate mortality among British military personnel based on 29 deaths. Even in the pre-PSA era, an increased diagnostic intensity in a group under special surveillance might lead to a higher incidence of prostate cancer and subsequently to a higher number of deaths attributed to the disease, as suggested by Feuer et al (26).

The increased risk of non-melanoma skin cancer was somewhat more marked than that of malignant melanoma. Our result for melanoma was in accordance with that among military men in the Nordic countries, while non-melanomas were not addressed (10). The major causal factor involved in development of skin cancer is exposure to ultraviolet (UV) radiation from sunlight (27). The elevated risk of non-melanoma skin cancer among vessel crews was also seen in the subgroup of submariners. We find it reasonable to assume that the excess is linked to intentional tanning although some exposure may take place during work hours in land-based or surface activity. In the study by Pukkala et al (10), elevated risk of melanoma and non-melanoma skin cancers was seen among highly educated professions including medical doctors, dentists, administrators, teachers and religious workers, while typical outdoor workers like farmers, forestry workers, gardeners and fishermen showed lowered risk, indicating that a social gradient and suggesting that leisure-time exposure is more important than occupational exposure.

There was sign of an increased risk of bladder cancer among submariners. Exposure to diesel exhaust could have occurred from diesel-powered engines, but the evidence of a causal link to bladder cancer is even weaker than that for lung cancer (28).

In conclusion, the present study gave no evidence of any excess of occupational disease and death apart from the asbestos-related risks found in a previous study, although the paucity of exposure data obviously hamper the opportunity to identify such risks. Differences between subgroups could partly be explained by differences in consumption of alcohol and tobacco.

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