ORIGINAL ARTICLE

Cancer incidence among Danish seafarers: a population based cohort study

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Aims: Seafarers aboard oil and chemical tankers may be exposed to many chemicals, including substances like benzene that are known to be carcinogenic. Other seafarers are exposed to engine exhaust, different oil products, and chemicals used aboard and some years ago asbestos was also used extensively in ships. The aim of this study was to study cancer morbidity among Danish seafarers in relation to type of ship and job title.

Methods: A cohort of all Danish seafarers during 1986–1999 (33 340 men; 11 291 women) registered by the Danish Maritime Authority with an employment history was linked with the nationwide Danish Cancer Registry and followed up for cancer until the end of 2002. The number of person years at risk was 517 518. Standardised incidence ratios (SIR) were estimated by use of the corresponding national rates.

Results: The SIR of all cancers combined was higher than expected: 1.26 (95% CI 1.19 to 1.32) for men and 1.07 (95% CI 0.95 to 1.20) for women. This was mainly due to an excess of cancer of the larynx, lung, tongue, mouth, pharynx, oesophagus, pancreas, kidney, urinary bladder, colon, and bone as well as skin melanomas among men (the three latter borderline significantly increased), and an excess of cancer of the lung, rectum, and cervix uteri among women. The differences in risk pattern for lung cancer between the different job categories among men ranged in terms of SIR from 1.2 (95% CI 0.9 to 1.7) (engine officers) to 2.3 (1.6 to 3.3) (engine room crew), and 4.1 (2.1 to 7.4) among maintenance crew. Non-officers had a 1.5 times higher lung cancer risk than officers. No increased occurrence of all lymphatic and haematopoietic malignancies combined was found for employees on tankers, but the number of cases was limited to a total of 7.

Conclusions: Danish seafarers, especially men, face an increased overall cancer risk, in particular a risk for lung cancer and other tobacco associated cancers.

Studies having explored cancer risk among seafarers are few, stem mainly from the Nordic countries, and have been based on relatively old cohorts. Most have reported an excess of cancer.[1] Some addressed male seafarers' risk of lung cancer, certain alcohol related cancers, or skin melanomas and found increased risks.[1–4] Two of these studies were based on information from death certificates.[3 4] The validity of the diagnosis was moderate and they did not include cancer types with a fair prognosis.[5] A large Nordic survey including 20 years of follow up for cancer morbidity was limited due to the use of the largely unspecific job titles taken from census data, including job information based on one day in 1970.[1]

Depending on their job contents and type of ship, certain subgroups of Danish seafarers may have been exposed to various potential carcinogenic agents during ship maintenance and freight handling. These agents include polycyclic aromatic hydrocarbon (PAH), diesel and gasoline exhaust gases, crude oil, and oil products among others.[6–9] Previous studies have pointed to an increased occurrence of mesotheliomas among engine room crew due to previous asbestos exposures and of leukaemia and lymphomas among deck crew on tankers, possibly due to benzene exposure.[10–12]

The Danish merchant fleet has some of the most modernised ships in the world. However, exposure to chemicals still occurs to a variable extent. Thus, recent measurements on board Danish tankers transporting benzene reported levels exceeding the Danish threshold limit values (TLVs) of benzene several hundred times near the tanks and three to five times in the living areas.[13] The Danish TLV of benzene is 1.6 mg/m3, corresponding to 0.5 ppm.

Finally, lifestyle, and social habits—which are often related to social position—are in general regarded as strong determinants for most cancers, particularly tobacco smoking and lung cancer.[14]

This nationwide follow up study aimed to investigate the cancer morbidity among Danish seafarers employed during the period 1986–99, their risk of lymphatic and haematopoietic malignancies in jobs with possible chemical exposure, their risk of lung cancer in jobs with possible PAH or asbestos exposure, and the cancer risk in relation to job title and type of ship.

MATERIAL AND METHODS

A cohort of Danish seafarers was established from individual data files kept at the Danish Seafarer Registry, a unique data source for studies of seafarers administered by the Danish Maritime Authority (DMA). It is compulsory for the shipping companies to send a copy of the employment contract to the DMA each time a seafarer signs on and off a Danish ship, and information is kept even after a person has retired or died. The Registry has been computerised since 1986 and includes information on name, date of birth, job title, name and call signal of the ship, and dates of start and end of each employment period. The Registry is regarded as almost complete.[15] In addition, seafarers with a permanent address in Denmark are registered with a unique 10 digit personal identification number (PIN) assigned to each resident in Denmark by the National Person Registry. The number includes information on date of birth, sex, and has a control digit. This number is used by all authorities and is the key

Abbreviations: DMA, Danish Maritime Authority; PAH, polycyclic aromatic hydrocarbon; SIR, standardised incidence ratio

identifier when establishing each seafarer's cancer history from the nationwide Danish Cancer Registry.

Study population

A total of 66 609 subjects (including people with and without residence in Denmark), with records of employments aboard Danish ships during the period 1 April 1986 to 31 December 1999 were initially retrieved from the files of the DMA.

Each seafarer (67%) with a valid PIN was retrieved in the Central Population Registry in order to identify place of residence, vital status, and date of possible death, emigration, or disappearance. As complete follow up for cancer is only feasible for those with a permanent residence in Denmark, we thus excluded 21 978 people (33%) without such residence (including 685 from Greenland), leaving 44 631 subjects (33 340 men and 11 291 women) for study (table 1). Among these, 97% of the males and 98% of the females were Danish citizens. Altogether they had 362 025 employment periods, and a total of 6390 seafarers (15%) were already employed at the first day of follow up. In total, 11 303 (25%) of the seafarers had only one employment during the period of follow up. In the most extreme case, one person had 159 employments. At the end of 1999, 11 299 seafarers were employed on Danish ships—a fourfold turnover (44 631/11 299) of the cohort. Only 101 people (0.2%) were employed from start to end of follow up. Table 1 gives further characteristics of the distributions of the included subjects such as age at start of follow up, period of first employment, vital status job category, and type of ship.

Follow up for cancer

Each person was linked to the files of the nationwide Danish Cancer Registry by use of their PIN. Since 1943 the Danish Cancer Registry has been registering information on all cancers diagnosed in Denmark, including type of cancer and date of diagnosis. Cancers are classified according to a modified version of the International Classification of Diseases, seventh revision (ICD-7).[16] Since 1968 the PIN has been assigned to each cancer case. The date of follow up began on 1 April 1986, or the date of first employment after this date. The follow up ended on the date of death, date of emigration, or disappearance obtained from the Central Population Registry, or on 31 December 2002, for those known to be living in Denmark at the closing date. In total 88.8% of the cohort members (28 936 men and 10 697 women) were alive at the end of follow up.

Table 1 Characteristics of seafarers* employed on Danish ships, 1986–1999

	Men (n = 33 340)		Women (n = 11 291)	
Characteristics	**n**	**%**	**n**	**%**
Age at start of follow up				
<20 years	6528	19.6	2116	18.7
20–29 years	12090	36.2	6201	54.9
30–39 years	5991	18.0	1310	11.6
40–49 years	5171	15.5	1132	10.0
⩾50 years	3600	19.6	532	4.7
Period of first known employment				
Before 1986	5783	17.3	841	7.4
1986–89	12130	36.3	4039	35.8
1990–94	7226	21.7	2529	22.4
1995–99	7201	21.6	3882	34.4
Vital status 31 December 2002				
Alive	29254	87.7	10709	94.8
Dead	2574	7.7	233	2.1
Emigrated	1467	4.4	344	3.0
Disappeared	45	0.1	5	0.1
Job category†				
All jobs				
Officers	5409	16.2	202	1.8
Engineers	4395	13.2	20	0.2
Deck crew	10374	31.1	535	4.7
Engine room crew	3198	9.6	29	0.3
Galley and catering crew	8632	25.9	10367	91.8
Other	1332	4.0	138	1.2
Type of ship‡				
Tankers	2210	6.6	431	3.8
Passenger ships	11253	33.8	8299	73.5
Other	21866	65.6	2561	22.7

*Person with a permanent residence in Denmark.
†Based on most recent employment (1986–99).
‡Based on longest held employment (1986–99).

Strategy of analysis

The specific type of ship was identified by its call signal, and all Danish ships were classified according to their main use in their active periods—for example, passenger ship, gas tanker, product/chemical tanker—by means of the Danish illustrated ship list and Danish ship list. Classification was performed by a person with experience in ship types (HLH).[17 18] Based on this categorisation scheme, each study participant was assigned with the type of ship.

The person years at risk for each seafarer was calculated from 1 April 1986 or the date of first employment after this date until 31 December 2002 or date of death, date of taking up residence abroad, or recorded day of disappearance before 31 December 2002. The standardised incidence ratio (SIR) was calculated as the ratio between the total number of observed site specific cancers and the total number of expected cases. The latter was calculated by multiplying the person years at risk during the follow up period in each five year age and calendar year group by the corresponding sex specific rates in the total Danish population. Their corresponding 95% confidence intervals (95% CI) were estimated assuming a Poisson distribution for the observed number of cancer cases.[19]

Evaluations also took into account (a) the type of ship for the longest known employment as a seafarer based on accumulated duration of employments on each type of ship (and specifically for tankers in table 3 for more than 50% of known employment time on tankers) and (b) job title for the most recent employment, because this was expected to reflect the social class to which the individual seafarer would belong. A lag time of a minimum of 10 years was also included when calculating SIRs, but as only minor differences in SIR estimates appeared compared with estimates without lag time included, we present only the latter estimates.

RESULTS

Among the 33 340 men and 11 291 women under study, the total number of person years at risk was 517 518 (395 537 for men and 121 982 for women). The proportion of employment time during the period of follow up was 22% (86 122 years/395 537 years) for the men and 11% (13 533 years/121 982 years) for the women. The number of person years at risk for men by most recent job title was: navigation officer (69 629), radio officer (3715), engine officer (56 966), deck crew (121 789), engine room crew (37 805), galley and catering crew (91 602), maintenance crew (7349), and others (6682). During follow up, a total of 1820 cancers (men, 1531; women, 289) occurred.

The SIR for all cancers combined was 1.26 (95% CI 1.19 to 1.32) for men, and 1.07 (95% CI 0.95 to 1.20) for women (table 2). The SIR for tobacco smoking associated cancers (oral cavity, oesophagus, stomach, liver, pancreas, nasal cavity, larynx lung, cervix uteri, kidney, and urinary bladder) was 1.6 (95% CI 1.5 to 1.7) for men and 1.5 (95% CI 1.2 to 1.9) for women. The SIRs for alcohol associated cancers (oral

Table 2 Standardised incidence ratios (SIR) for cancer 1986–2002 among Danish seamen

		Men (395 537 person years)			Women (121 982 person years)		
ICD-7*	Site	Obs	SIR	95% CI	Obs	SIR	95% CI
140	Lip	11	1.75	0.87 to 3.13	0	–	–
141	Tongue	14	1.87	1.02 to 3.13	0	–	–
143–144	Mouth	37	2.69	1.90 to 3.71	0	–	–
145–148	Pharynx	45	2.47	1.80 to 3.30	1	0.95	0.01 to 5.30
150	Oesophagus	33	1.61	1.11 to 2.26	2	2.24	0.25 to 8.10
151	Stomach	37	1.39	0.98 to 1.91	1	0.48	0.01 to 2.68
153	Colon	90	1.24	1.00 to 1.52	12	1.17	0.61 to 2.05
154	Rectum	59	1.23	0.93 to 1.58	11	2.37	1.18 to 4.24
155.0	Liver	17	1.52	0.89 to 2.44	2	2.16	0.24 to 7.79
155.1	Gall bladder	6	1.28	0.47 to 2.79	1	1.43	0.02 to 7.96
157	Pancreas	44	1.72	1.25 to 2.30	5	1.64	0.53 to 3.83
160	Nasal cavity	3	0.98	0.20 to 2.86	1	3.11	0.04 to 17.31
161	Larynx	45	2.14	1.56 to 2.87	3	3.90	0.78 to 11.4
162	Lung	259	1.61	1.42 to 1.82	29	1.70	1.14 to 2.44
162.2	Pleura†	6	0.99	0.36 to 2.16	0	–	–
170	Breast	1	0.53	0.01 to 2.92	72	0.98	0.77 to 1.24
171	Cervix uteri	–	–	–	33	1.59	1.09 to 2.23
175	Ovaries	–	–	–	15	1.32	0.74 to 2.18
177	Prostate	82	1.03	0.82 to 1.27	0	–	–
178	Testis	62	0.93	0.71 to 1.19	0	–	–
180.0	Kidney	49	1.37	1.01 to 1.81	2	0.71	0.08 to 2.58
181	Urinary bladder	106	1.26	1.03 to 1.52	1	0.25	0.00 to 1.38
190	Melanoma	67	1.26	0.98 to 1.60	23	1.15	0.73 to 1.72
191	Other skin	233	1.05	0.92 to 1.19	32	0.74	0.50 to 1.04
193	Brain	51	0.91	0.68 to 1.20	16	1.22	0.70 to 1.99
194	Thyroid	6	1.18	0.43 to 2.56	3	0.72	0.15 to 2.11
196	Bone	7	2.55	1.02 to 5.25	0	–	–
197	Connective tissue	5	0.71	0.23 to 1.66	0	–	–
201	Hodgkin's disease	17	1.27	0.74 to 2.04	1	0.31	0.00 to 1.71
200, 202	Non-Hodgkin's lymphoma	41	1.01	0.73 to 1.38	5	0.86	0.28 to 2.01
203	Multiple myeloma	12	0.91	0.47 to 1.59	1	0.77	0.01 to 4.30
204	Leukaemia	23	0.72	0.46 to 1.09	2	0.48	0.05 to 1.74
205	Mycosis fungoides	2	2.90	0.33 to 10.5	1	12.9	0.17 to 71.9
	Other and unknown	61	0.98	0.74 to 1.27	14	1.11	0.61 to 1.86
140–205	All sites	1531	1.26	1.19 to 1.32	289	1.07	0.95 to 1.20

*National Board of Health, 2003.
†Includes mesothelioma.

cavity, oesophagus, liver, larynx) were also significantly increased among men. Borderline significantly increased SIRs for men were found for colon cancer (1.2 (95% CI 1.0 to 1.6)), bone cancer (2.6 (95% CI 1.0 to 5.3) and for melanomas (1.3 (95% CI 1.0 to 1.6)). Among women, the SIRs for rectum cancer were also increased in 11 cases (95% CI 2.4 (1.2 to 4.2). No cancer type incidences were found to be significantly lower than in the general population either among the men or women (table 2). The SIR for pleural cancer, including mesotheliomas, was not increased.

We observed no increase in the occurrence of lymphatic and haematopoietic malignancies among male seafarers, either for the entire group (table 2) or within the subgroup whose longest employment duration was onboard tankers (table 3). Detailed analyses based on job title gave no further information (data not shown).

The SIRs for lung cancer by job category among men ranged from 1.2 (95% CI 0.9 to 1.7) (engine officers) to 2.3 (95% CI 1.6 to 3.3) (engine room crew) and to 4.1 (95% CI 2.1 to 7.4) among maintenance crew (table 4). In general, the

Table 3 Standardised incidence ratios (SIR) for lymphatic and haematopoietic cancers (1986–2002) among male seafarers with longest duration of employment at tankers*

Site†	Obs	SIR	95% CI
Hodgkin's disease (201)	2	1.9	0.2 to 6.9
Non-Hodgkin's lymphoma (200, 202)	2	0.6	0.1 to 2.1
Multiple myeloma (203)	–	–	–
Leukaemia (204)	3	1.1	0.2 to 3.3
Mycosis fungoides (205)	–	–	–
All lymphatic tissue (200–205)	7	0.8	0.3 to 1.7

*More than 50% of known employment time on tankers.
†National Board of Health. 2003.

Table 4 Standardised incidence ratios (SIR) for primary lung cancer among men by latest held job category

Latest held job category	Obs	SIR	95% CI
Navigation officer	76	1.3	1.0 to 1.6
Radio officer	4	1.4	0.4 to 3.5
Engine officer	36	1.2	0.9 to 1.7
Ratings, deck	64	1.9	1.4 to 2.4
Engine room crew	33	2.3	1.6 to 3.3
Catering crew	19	2.1	1.3 to 3.2
Galley crew	15	1.7	1.0 to 2.9
Maintenance crew	11	4.1	2.1 to 7.4
Other	1	1.4	0.0 to 7.8
Total	259	1.6	1.4 to 1.8

Table 5 Standardised incidence ratios (SIR) for primary lung cancer and all cancers among men by type of ship* and officer status†

	Officers			Non-officers		
Type of ship*	Obs	SIR	95% CI	Obs	SIR	95% CI
Dry cargo vessels (including container ships)						
Lung cancer	29	1.5	1.0 to 2.1	45	2.6	1.9 to 3.5
All other cancers	144	1.1	0.9 to 1.3	163	1.3	1.1 to 1.6
Passenger ships						
Lung cancer	23	1.0	0.6 to 1.5	51	1.6	1.2 to 2.1
All other cancers	147	1.1	0.9 to 1.4	259	1.2	1.0 to 1.3
Tankers and gas tankers						
Lung cancer	15	1.4	0.8 to 2.3	26	3.0	2.0 to 4.5
All other cancers	86	1.2	1.0 to 1.5	73	1.3	1.0 to 1.7
Smaller ships, supply ships						
Lung cancer	47	1.3	1.0 to 1.7	23	1.9	1.2 to 2.8
All other cancers	263	1.3	1.1 to 1.4	137	1.1	1.0 to 1.3
All ships						
Lung cancer	114	1.2	1.1 to 1.5	145	2.1	1.8 to 2.5
All other cancers	640	1.3	1.1 to 1.3	632	1.2	1.1 to 1.3

*Based on longest held employment.
†Based on latest held job.

SIRs for officers (navigation officers, radio officers, and engine officers) were lower than for non-officers. This social gradient is further explored in table 5, which shows the SIR for lung cancer and all other cancers combined by type of ship and officer status. A significant increase in the SIRs for both lung cancer and all other cancers combined was seen for both social groups. Within each category the SIR for lung cancer was significantly lower among officers (1.2 (95% CI 1.1 to 1.5)) than among non-officers (2.1 (95% CI 1.8–2.5)). Finally, longest employment at a passenger ship tended to be associated with the lowest SIR for lung cancer both among officers (1.0 (95% CI 0.6 to 1.5) and among non-officers (1.6 (95% CI 1.2 to 2.1). In contrast, the highest SIR for lung cancer in both groups was found among seafarers employed on dry cargo vessels (including container ships) and tankers.

DISCUSSION

In this historic follow up study, we found a significantly increased overall relative risk of cancer among men in a comparatively young cohort of Danish seafarers. This increase was related to an excess of all cancers associated with tobacco smoking and alcohol and an excess of colon cancer and bone cancer among men. Women also had an excess of cancers associated with tobacco and a significant excess of cancer of the rectum. The relative risk for lung cancer was higher among non-officers than among officers, and tended to be highest in maintenance and engine room crew and among non-officers working on tankers and gas tankers and on dry cargo vessels.

The main strength of the present study is that it is based on recent data and boasts a richness of employment detail, drawing data on duration of employment, type of ship, and job category from the Danish Seafarer Registry, and similarly valid information on incident cancers from the Danish Cancer Registry. Possible weaknesses include the relatively young age of the cohort, the necessary exclusion of non-Danish residents, the high turnover of the cohort indicating relatively short time exposures, and the relatively short follow up period with a maximum of 17 years. Due to the relatively young age of the cohort members, the study provided a rather short follow up time for most cancers. Even if the ''healthy worker effect'' is less pronounced in studies of cancer, the use of the total Danish population as the reference group may have entailed lower SIR estimates especially for the tobacco and alcohol associated cancers in our study. Still, we found high SIR estimates for these cancers. In the analysis of job title, we decided to use the job title for the most recent employment. This may, however, give rise to misclassification, because some seamen may have been promoted to officers, which will imply that exposure patterns for these participants have changed. In the last decades, however, almost all officers have started as cadets before becoming officers and few go through the traditional hierarchy from deck boy to captain.

Lung cancer is known to be strongly associated with tobacco smoking but also with other risk factors, including occupational exposures.[1–4] No information was available on individual smoking habits in the present cohort, and tobacco smoking may be an important confounder when evaluating traditional occupational risk factors for lung cancer like asbestos or PAH exposures. Seafarers smoke more than the general population and in amounts comparable to those of blue collar workers. A study from 1994 found that 58% of the officers and 79% of the non-officers were smokers.[20] This fact can, however, only partly explain the high occurrence of lung cancer seen among male seafarers where the differences in risk pattern between the different job categories range in terms of SIR from 1.2 (95% CI 0.9 to 1.7) among engine officers to 4.1 (95% CI 2.1 to 7.4) among maintenance crew. It also cannot explain the difference between the increased cancer risk of non-officers compared with officers.[20 21] Former studies have pointed to the particular problems encountered by engine room personnel as a result of exposure to oil mist and hydrocarbon vapour (aliphatic hydrocarbons) in the air and cutaneous exposure to PAH in used engine oils.[6 7 10 22 23] Crew working on car decks, passenger ships, and roll on/roll off ships may, during certain working hours, be exposed to significant amounts of *exhaust gases*, including exposure to diesel particles and PAH. Female seafarers, who are rarely exposed to occupational carcinogens, had a cancer pattern similar to that of the male seafarers, even if their excess cancer risk was less pronounced (SIR for lung cancer 1.7 (95% CI 1.1 to 2.4)) which may represent an argument against a strong contribution of occupational exposures to the risk of lung cancer. The difference in SIR for lung cancer reflects, however, a distinct difference in occupational and lifestyle exposures associated with seafaring.

Our follow up study demonstrated no excess of lymphomas or leukaemia among seafarers working on tankers, as opposed to the observations made in two nested case control studies of Finnish and Swedish seafarers.[10 11] In our study the

Main messages

- Male Danish seafarers have a high overall relative risk of cancer that is related to an excess of all cancers associated with tobacco smoking and alcohol and a borderline increased excess of colon cancer, bone cancer, and skin melanomas. Female Danish seafarers also have an excess of lifestyle related cancers associated with tobacco smoking and an excess of cancer of the rectum.
- The cancer morbidity among seafarers depends on their job title and the type of ship on which they are working. The reported risk figures therefore presumably reflect a social gradient and possibly a difference in occupational exposures.
- No increased occurrence of all lymphatic and haematopoietic malignancies combined was found for employees on tankers; however the number of cases was limited to a total of seven.

Policy implications

- We recommend preventive measures aimed at countering the adverse effects of lifestyle factors among seafarers as well as continuous follow up on effects of occupational exposures.

number of leukaemia and lymphomas in tanker personnel was limited to a total of seven cases.

A potential limitation in our study was the exclusion of all seafarers without Danish residence (33%), as it was only possible to a follow up on Danish residents through the Danish Cancer Registry. During the period 1986–2002, the number of foreign seafarers employed on Danish ships has grown. The foreign seafarers have mainly been employed as deck and engine room crew and seafarers within these job categories are usually more frequently exposed to toxic substances, including carcinogens; this may result in an underestimation of the cancer risk associated with such exposures.

The finding of an increased SIR for bone cancer among men and rectum cancer among women has not been reported before and a chance finding cannot be excluded. The increased SIR for colon cancer among men may be due to dietary factors or lack of physical activity.[24] The borderline significantly increased SIR for men for skin melanomas, a cancer which is known to be strongly associated with ultraviolet radiation, may be due to outdoor work on ships sailing to areas with high sun exposure.[2]

In contrast with other studies, we found no increased risk of mesothelioma among any job category at sea, not even among engine room personnel.[2 4 10] This could be due to the relatively young cohort and the ban of asbestos in new Danish ships in 1975.

In conclusion, using recent and more detailed register data than former studies, this study reports an increased occurrence of primarily tobacco associated cancers among Danish seafarers. The study also showed an increased lung cancer risk for non-officers compared with officers. Cancer studies reflect the exposures of the past. Still, recent validated measurements on tankers have shown examples of benzene exposures exceeding threshold limits and there is a need for continuous follow up on effects from such exposures. At the same time, we need preventive measures to counter the adverse effects of lifestyle factors among seafarers, in particular tobacco smoking.

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