Exposure to Mineral Oil Mist and Respiratory Symptoms in Marine Engineers

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The purpose of the study was to see if marine engineers have an increased prevalence of respiratory symptoms, and if so whether it can be related to occupational exposures.

A self-administered questionnaire was sent to 700 male seamen from three Norwegian ferry companies. Of the 492 respondents, 169 were currently working as marine engineers and 295 had never worked as marine engineers. The outcomes of cough and wheezing, chronic bronchitis, severe dyspnea, any dyspnea, and mucous membrane irritation (MMI) were defined from the questionnaire. Age and smoking-adjusted prevalences of these respiratory conditions were compared between the groups. Logistic regression was used to further elucidate the explanatory variables. The exposure assessment indicated an exposure (TWAC) to oil mist for marine engineers in the range from 0.12 to 0.74 mg/m^3 *(mean 0.45 mg/m*^{3}*)*

When comparing current marine engineers with those who had never worked as marine engineers, the prevalence ratios were 1.38 (95% CI 1.0–1.9) for MMI, 1.53 (95% CI 1.2–1.9) for any dyspnea, and 1.63 (95% CI 1.0–2.6) for severe dyspnea. The differences remained for some of the symptoms after controlling for self-reported former asbestos exposure in the regression analysis.

The increased prevalence of respiratory symptoms found among marine engineers in this investigation may partly be explained by oil-mist exposure, or more probably by a combination of past asbestos exposure and past and present oil-mist exposure. Am. J. Ind. Med. 32:84–89, 1997. *© 1997 Wiley-Liss, Inc.*

KEY WORDS: marine engineers; respiratory symptoms; engine room; questionnaire; ferries; mineral oil mist; MWF

INTRODUCTION

Exposure to mineral oil mist can cause harmful effects in the airways. Different types of oils are used for fuel and for lubrication in the engine rooms of ships. Oil mist is generated by moving machine parts and the aerosolization of vaporized oil. The working environment of seamen and marine engineers in regard to exposure to oil mist, and the possible deleterious health outcomes from such exposure, has not, to our knowledge, been investigated previously. However, an increased incidence of lung cancer has been observed among seamen [Rafnsson et al., 1995; Rapiti et al., 1992], especially for engine room personnel [Brandt et al., 1994; Rafnsson et al., 1988] and among seamen who have been working on tankers [Moen et al., 1990]. A previous Norwegian study [Baksaas et al., 1983] of sailors showed a 50% increased standardized incidence ratio for total cancer. The cause of the increased cancer risk has been assumed to be occupational exposures, particularly to asbestos, and that there is a greater proportion of smokers among seamen when compared to the general population [Baksaas et al., 1983]. Other studies have demonstrated radiological abnormalities

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regarded as consistent with asbestos exposure in chest X-rays of merchant seamen [Velonakis et al., 1989]. This occurred, in particular, among those employed in the engine department [Selikoff et al., 1990]. A search of the literature found no previous investigation regarding the prevalence of respiratory symptoms in seafarers.

Investigations of workers exposed to oil mist have shown that such exposure may have deleterious effects on the lungs, even at relatively low levels. Workers exposed to low levels (0.15–0.30 mg/m^3) of mist and vapor of mineral oils for 5–35 years in a Norwegian cable plant had an increased prevalence of slight basal lung fibrosis [Skyberg et al., 1986]. An increased prevalence of respiratory symptoms [Järvholm et al., 1982] and pulmonary fibrosis [Cullen et al., 1981; Lingen et al., 1957] in oil-mist exposed workers have also been found in other investigations. In addition, several experimental studies [Wagner et al., 1964; Skyberg et al., 1990] have provided evidence of adverse effects on the respiratory organs from high exposures to oil mist. In some early German animal studies with inhalation of mineral oil mist, granulomatous changes with fibroblasts were identified by electron microscopy. This granuloma formation was explained by retention of mineral oil in interstitially localized macrophages [Eckert and Slawa 1978; Eckert et al., 1979]. On the other hand, there were also investigations of workers occupationally exposed to mineral oil mist which have shown no increase in respiratory mortality or morbidity [Goldstein and Benoit, 1970; Järvholm et al., 1981].

The present study investigated whether marine engineers have an increased prevalence of respiratory symptoms, and if so whether this can be linked to occupational exposure.

MATERIALS AND METHODS

Study Participants

As seafarers are a group with a special lifestyle, we chose to compare the marine engineers with other seafarers. Lists of eligible participants were obtained from three local ferry companies. A self-administered questionnaire was mailed to all employees of these companies working at sea. The questionnaires were mailed between June and September 1993. Non-responders received one reminder.

Of the 700 seamen who received the questionnaire, 208 did not respond. Of the 492 respondents, 169 were currently working as marine engineers, while 295 had never worked as marine engineers, and served as controls. The remaining 28 were former marine engineers currently working at other sites on the ship. Of the 197 respondents who had ever worked as marine engineers, 152 had done so for more than five years. The ships were small to middle-sized coastal ferries trafficking fjords in the middle part of Norway. The ferry trips take from 10 to 20 minutes and there are between 20 to 70 departures every day. The seamen stay on the ferry for two weeks, then have two weeks leave.

Exposure Conditions

All the current and former marine engineers are or have been exposed to oil mist to some extent. Two types of oils are used in the engine room, one a lubricating oil (boiling point (b.p.) 300–700°C), and one a fuel oil (b.p. 175–300°C).

The exposure to oil mist in the engine rooms was assessed by area measurements, task measurements, and registration of the working patterns of the average marine engineer. Area measurements were performed in the engine rooms of 19 coastal ferries belonging to the companies from which the study group was obtained. Two samples were collected at the same time in each engine room. Sampling of oil mist was performed using 37 mm diameter double glass fiber filter (Nucleopore glass fibre filter AAA). The flow rate was 2 liter/min and the sampling time varied from 60 to 120 min. The analyses of oil mist on the filters were performed as described in an earlier publication [Svendsen et al., 1996].

Task measurements were performed by an optical aerosol monitor (Casella AMS950) connected to a data logger (Grant Squirrel 1207). In that way we obtained semiquantitative values for the exposure during different working operations. The results obtained were adjusted to the concentrations determined from the filter measurements by logging with Casella and simultaneous sampling for some measurements. The specifically monitored working operations (tasks) were pressure testing of valves, control of the crank case of the main engine, testing of the compressor, and maintenance of the propeller shaft.

The actual exposure level for the average marine engineer was calculated as a time weighted average concentration (TWAC). This was based on the measurements, also taking into consideration the time spent in the engine room each day and how often tasks entailing exposure above background concentrations were performed.

Work as a marine engineer may also, to some extent, involve exposure to engine exhaust and previously also to asbestos, which was extensively used for insulating purposes in the engine rooms of Norwegian ships from the 1950s up to the 1970s. As the use of asbestos for insulating purposes was banned in 1977, the exposure to asbestos has now almost ceased on Norwegian ships.

Questionnaire

In addition to questions about respiratory symptoms, the questionnaire included questions about age, smoking habits, education, earlier allergic disease or lung disease, and work history. The questions on respiratory symptoms were based on the MRC questionnaire on chronic bronchitis [Medical Research Council, 1966].

The outcome of the study was the reported impact on the respiratory health of the study participants. This was defined as mucous membrane irritation (MMI), cough and wheezing, any dyspnea, severe dyspnea, and chronic bronchitis. A participant was regarded as having MMI if he reported irritation in the nose or the throat for as long as 1–2 months during the previous year. Cough and wheezing were considered to be present if the participant reported cough with or without phlegm or wheezing for as long as 1–2 months during the previous year.

A subject was regarded as having any dyspnea if he reported any form of dyspnea in the past or at present. Severe dyspnea was defined as shortness of breath after climbing two stairs at ordinary speed, ordinary walking on level ground, or at rest.

Chronic bronchitis was defined as cough with phlegm for at least three months during two consecutive years.

In regard to smoking habits, ‘‘never smokers’’ were defined as persons who reported that they had never smoked regularly. ‘‘Current smokers’’ were all who reported smoking at present or who had stopped smoking less than five years ago. Ex-smokers were those who had stopped smoking more than five years ago.

Statistical Methods

The statistical analysis of the data was performed by means of the Statistical Package for the Social Sciences (SPSS/PC+) and the EPI Info program. In a bivariate analysis, the prevalence rates were standardized for age and smoking by the direct method, based on the age distribution and the distribution of smoking habits between marine engineers and controls. Confidence intervals for the given prevalence ratios were determined using the Mantel-Haenszel approach.

Outcomes which showed statistically significant differences in the bivariate analysis were selected for further multivariate analysis by logistic regression. The independent variables included in the model were supposed determinants for lung diseases such as ‘‘self-reported asbestos exposure in the past,’’ ‘‘self-reported oil mist exposure in the past,’’ ‘‘self-reported exposure to welding fumes in the past,’’ ‘‘self-reported exposure to other irritating gases or fumes in the past,’’ the number of ‘‘years worked as a marine engineer,’’ ‘‘age,’’ ‘‘smoking habits,’’ and being a ‘‘current marine engineer.’’ In the logistic regression analysis, smoking was defined as grams tobacco smoked each week for current smokers.

RESULTS

Exposure to Mineral Oil Mist

The mean concentration of oil mist in the engine rooms of the ferries was 0.20 mg/m^3 (SD = 0.13), calculated as an arithmetic mean from 38 measurements carried out in the 19 ferries. The mean level of oil mist during the particular tasks measured was 1.3 mg/m^3 (SD = 0.6), calculated as an arithmetic mean from four different tasks with 2–4 measurements for each task. The two tasks with the highest exposure were pressure testing of valves (2 mg/m^3) and maintenance of the propeller shaft (1.5 mg/m^3).

The mean TWAC for the marine engineers participating in the study was estimated as 0.45 mg/m^3, based on 5 hr with the mean background level and 2 hr at the elevated level when doing specific tasks. The lowest TWAC that could be estimated was 0.12 mg/m^3, based on a background level of 0.1 mg/m^3 with 3 hr a day spent in the engine room and doing specific tasks for 0.5 hr. The highest estimated TWAC was 0.74 mg/m^3, based on a background level of 0.4 mg/m^3 with 5 hr spent in the engine room and doing specific tasks for 3 hr.

Results From the Questionnaire

According to information given in the questionnaire, the 492 study participants were divided into 169 ‘‘current marine engineers’’ who were currently working as marine engineers, and 295 controls who had other duties on the ship and had never worked in the engine room. In addition, there were 28 men who had previously worked as engineers, but who had other duties on the ship at the time of the study. The background variables of the subgroups of the study population are presented in Table I. The group of marine engineers were older than the controls and had a greater proportion of smokers. However, the smoking marine engineers had a lower weekly consumption of tobacco than the controls.

‘‘Current marine engineers’’ reported exposure to oil mist, asbestos, welding fumes, and other irritating agents in earlier jobs more often than the controls. The proportions of the marine engineers and the controls who reported such exposure in the past are shown in Table II.

Table III presents the bivariate analysis of age and smoking-adjusted prevalence and prevalence ratios of the defined respiratory conditions. The ‘‘current marine engineers’’ had a higher prevalence of all respiratory conditions when compared with the controls. The differences in prevalence of ‘‘MMI,’’ ‘‘any dyspnea,’’ and ‘‘severe dyspnea’’ were statistically significant at a 5% level. The crude analysis of respiratory morbidity of the controls showed no differences between deck hands and ship officers.

TABLE I. Background Variables for the Study Subgroups of Current Marine Engineers, Former Marine Engineers, and Controls

	Current Marine Engineers n = 169	Former Marine Engineers n = 28	Controls n = 295
Age (mean, sd)	46.6 (9.6)	43.1 (8.7)	42.5 (9.8)
Current smokers (%)	59.2	64.3	54.6
Ex-smokers (%)	22.5	21.4	21.0
Never smokers (%)	16.6	14.3	24.1
Grams tobacco/week (for current and ex-smokers)	103	108	112
Kg tobacco cumulative (for all)	102	109	90
Years as an engineer	20.9	6.5	0
Years as a seaman	24.0	22.8	22.1

TABLE II. Proportions (%) of the 169 Marine Engineers and the 295 Controls Who Reported Exposure to Oil Mist, Asbestos, Welding Fumes and Other Air Contaminants in the Past

	Current Marine Engineers	Controls
Oil mist exposure in the past	62.1	24.7
Asbestos exposure in the past	40.8	9.8
Welding fumes exposure in the past	50.9	11.5
Other irritating gases, exposure in the past	39.6	19.0

When a subgroup of present and former engineers who all had more than five years of service (n = 165) were compared with the control group, only the age- and smoking-adjusted prevalence ratio for cough and wheezing was statistically significant, 1.47 (95% CI 1.15–1.86).

The results from a logistic regression analysis of the outcomes ‘‘severe dyspnea,’’ ‘‘any dyspnea,’’ and ‘‘MMI’’ in relation to possible explanatory variables are presented in Table IV. Age and smoking habits were also included in the model.

DISCUSSION

The present study is a cross-sectional study aimed at elucidating whether marine engineers have impaired respiratory health when compared to other seamen on the same type of ships. A particular problem arose concerning selection bias, as the seamen must pass a medical checkup every second year. The seaman may risk losing his license to sail if serious obstructive lung disease is found. There is, therefore, a possibility that if a higher prevalence of serious lung disease does exist among the marine engineers, more marine

TABLE III. Age- and Smoking-Adjusted Prevalence Rates (%) and Prevalence Ratios for Defined Respiratory Conditions Among Current Marine Engineers and Seamen Who Have Never Worked as Marine Engineers (Controls) (95% confidence intervals for the prevalence ratios are given in parenthesis)

Symptoms	Current Marine Engineers n = 169	Controls n = 295	Prevalence Ratios Engineers/ Controls
Mucous membrane irritation (MMI)	35.6	26.0	1.38 (1.03–1.86)
Cough or wheezing	24.2	24.4	1.00 (0.70–1.44)
Any dyspnea	46.5	30.8	1.53 (1.21–1.93)
Severe dyspnea	17.0	10.3	1.63 (1.01–2.63)
Chronic bronchitis	13.2	10.6	1.24 (0.74–2.07)

engineers would have been selected out, which would have resulted in an underestimation of the true relative risk. Otherwise there is little reason to assume that this selection bias acts differently between the marine engineers and the controls.

In the present study, there may be some reason to assume that the response rate for the engineers was somewhat higher than for the controls. However, as we could also assume that the controls who responded were less healthy than the non-respondents, the possible small underrepresentation of controls has probably not led to any decisive overestimation of the relative risk.

Our measurements and calculations indicate an exposure to oil mist for marine engineers in the range from 0.12 to 0.74 mg/m^3 (mean 0.45 mg/m^3). This is a crude estimate, but a more detailed personal exposure assessment was not possible with the data available. During their career at sea, the marine engineers are usually transferred from ship to ship. A typical marine engineer in this study had been working on 5–15 different vessels. This fact would have made an individual exposure assessment very complicated. We therefore considered the exposure estimates given to be rather probable as a group average.

Only the difference in the prevalence of mucous membrane irritation and dyspnea reached statistical significance at the 5% level in the study. The symptom, dyspnea, is rather unspecific and may reflect various other conditions besides lung disease, such as overweight, lack of exercise, or cardiovascular disorders. We have, however, little reason to assume that such conditions would be distributed differently between the marine engineers and the seamen who were used as controls.

TABLE IV. Multivariate Association Between Some Explanatory Variables and the Outcomes ''Severe Dyspnea,'' ''Any Dyspnea,'' and ''MMI'' (all variables are corrected for each other and adjusted for age and smoking habits)

	Severe Dyspnea OR (95% C.I.)	Any Dyspnea OR (95% C.I.)	MMI OR (95% C.I.)
Current marine engineer	1.8 (1.0–3.5)	2.0 (1.3–3.3)	1.2 (0.7–2.0)
Self-reported asbestos exposure	2.4 (1.1–5.1)	1.5 (0.8–2.7)	1.1 (0.6–2.1)
Self-reported exposure to welding fumes	0.9 (0.4–2.0)	0.8 (0.4–1.5)	1.6 (0.9–2.9)
Self-reported exposure to other irritating gases/fumes	0.6 (0.3–1.2)	1.0 (0.6–1.7)	2.0 (1.2–3.3)

Some previous studies have found lung fibrosis [Skyberg et al., 1986; Cullen et al., 1981; Lingen and Sundell, 1957] and an increased prevalence of respiratory symptoms [Järvholm et al., 1982; Ameille et al., 1995], including dyspnea on exertion [Cullen et al., 1981], in mineral oil mist-exposed workers. Lung fibrosis, determined from chest X-rays, was found in workers exposed to oil mist in the range of 0.15–0.30 mg/m^3 [Skyberg et al., 1986], i.e., concentrations at the same level as in the engine rooms in the present study. Our results are in accordance with the previous observation regarding respiratory symptoms among oil mist-exposed workers [Robertson et al., 1988; Cullen et al., 1981].

After controlling for ''self-reported asbestos exposure in the past,'' ''age,'' and ''smoking,'' indications of more lung impairments among engineers than among the controls remained. Thus, factors other than asbestos exposure may also play a role in the causation of respiratory symptoms among the marine engineers. Asbestos exposure is no longer a factor in most Norwegian vessels, but exposure to oil mist at relatively low levels is still present. There is reason to assume that marine engineers are more aware of former asbestos exposure (as the focus on asbestos in the media has been rather intense), than of oil-mist exposure. In fact, it is quite certain that all the marine engineers have been exposed to oil mist to some degree, while only 62-64% reported this. Thus the variable ''current marine engineer'' is probably the best indicator of oil-mist exposure.

The increased prevalence of lung symptoms found in this investigation may be partly explained by oil-mist exposure, or more probably by a combination of past asbestos exposure and past and present oil-mist exposure.

Earlier investigations have shown that seafarers have an increased risk of lung cancer [Baksaas et al., 1983; Rafnsson et al., 1995; Rapiti et al., 1992]. An excess incidence of lung cancer among seamen has been related mainly to previous exposure to asbestos [Rapiti et al., 1992; Rafnsson et al., 1988; Velonakis et al., 1989; Selikoff et al., 1990]. However, as it has been shown in the present and in previous investigations that oil-mist exposure at levels found in ship engine rooms can cause lung impairments, there is probably reason to consider mineral oil mist as a possible carcinogenic risk factor for marine engineers.

This investigation is one of the first studies on oil-mist exposure in ship engine rooms and respiratory symptoms among marine engineers. In addition to an extension of the present study regarding radiographic changes and lung function in the participants, there is reason to suggest that more studies be carried out on different kinds of vessels in order to further characterize oil-mist exposure. There is, in our opinion, also a need for further studies on health outcomes in larger groups of exposed individuals.

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