Respiratory symptoms, lung functions, and exhaled nitric oxide (FE_{NO}) in two types of fish processing workers: Russian trawler fishermen and Norwegian salmon industry workers

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Objective: Respiratory outcomes and work-related factors were studied in two seafood worker populations representing different occupational environments.
Methods: Levels of fractional exhaled nitric oxide (FE_{NO}), spirometric values, prevalence of respiratory symptoms, and self-evaluated exposures were compared between 139 Norwegian salmon workers and 127 Russian trawler workers.
Results: Increased odds ratios (ORs) of shortness of breath with wheezing and prolonged cough as general respiratory symptoms were found in salmon workers, while increased ORs of work-related dry cough and running nose were found in trawler fishermen. Both worker groups ranked ''cold work environment,'' ''use of disinfectants,'' and ''contaminated indoor air'' as the first, second, and third most important causes of work-related respiratory symptoms, respectively. Fractional exhaled nitric oxide levels were higher in asthmatic trawler workers compared to asthmatic salmon workers.
Conclusions: Respiratory symptoms commonly associated with obstructive airway diseases were more prevalent in salmon workers, while symptoms commonly associated with asthma and short-term effects of cold air exposure were more prevalent in trawler workers.

Keywords: Respiratory symptoms, Asthma, Seafood workers, FE_{NO}, Spirometry, Epidemiology, Ambient temperatures

Introduction

Increased prevalence of airway symptoms and decreased lung function as measured by spirometry are reported for various kinds of seafood workers.[1–13] However, little is known about the similarities and differences in symptom profiles and lung function outcomes in workers from different types of seafood workers. Negative respiratory effects may be associated with workplace and/or individual factors. Workplace factors most commonly correlated with respiratory effects are air temperature and exposure to various chemical and biological agents suspended in air. Individual factors include smoking history, atopy, and existing airway morbidity.

The seafood industry is of great importance to the economy in northern Norway and Russia. The Northwestern Russia seafood industry differs from the Norwegian and Scandinavian industries in the extensive use of factory trawlers, where fish are processed and frozen onboard. The factory facilities on board are most often located on the lower decks of the ships in confined and narrow spaces with semiautomatic or manual process lines and natural ventilation. The Norwegian salmon industry has experienced rapid growth in the last two to three decades and is characterized by modern factories on land with 50–200 employees processing fresh and frozen products with a high degree of automation. The production areas are typically outfitted with mechanical ventilation systems.

Moderately low temperatures characterize the production areas of both workplaces. However, while salmon workers are in a relatively stable thermal environment, trawler workers are exposed to thermal variations from harsh outdoor climate through open hatchways during loading and unloading activities

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and occasional outdoor tasks. Breathing cooled indoor air has been shown to elicit physiological responses at airway surfaces, including swelling of nasal mucosa, increased nasal secretion, and narrowing of nasal passages.[14] Tracheobronchial walls have to cope with incomplete warming and conditioning of inspired air, which may lead to lower airway symptoms.[15]

Bioaerosols containing various organic materials are present in the workplace atmospheres of all kinds of seafood industry.[16–18] Automated and manual processing of seafood can produce high levels of inhalable bioaerosols, as can cleaning with high-pressure water beams and nozzles along the production lines. Bioactive agents in the bioaerosols such as allergens, enzymes, microorganisms, and microbial toxins may give rise to irritative or immunological respiratory symptoms when inhaled.[8,18,19] Besides bioaerosols, seafood workers may be exposed to chemical agents from disinfectants, which are commonly used to clean production areas and have been shown to trigger irritation of the airways as well as atopic sensitization.[20,21]

In this study, Russian factory trawlers and Norwegian salmon factory workers involved in line processing (and not fishing) were compared to identify similarities and differences in respiratory symptom profiles, respiratory test outcomes, perception of causative factors for airway symptoms, and individual characteristics. Results from this study can be used as a foundation for future research on causative factors for airway effects in seafood industry workers.

Materials and Methods

Study design and population

Data from this study came from two cross-sectional surveys completed by full-time employees at five salmon factories in Norway and trawler fishermen employed at Arkhangelsk Trawl fleet in Russia. Both study populations were engaged in seafood processing and were exposed to seafood during work activities involving slaughtering and fileting of fish. The Norwegian surveys were carried out between November 2007 and April 2008 and the Russian surveys between December 2009 and January 2010. A detailed description of the study design and methods has been reported previously.[22,23] All study subjects were informed about the study objectives and requirements for participation. Written informed consent was obtained from each participant. The Regional Committee for Medical Research Ethics in Northern Norway, the Norwegian Data Inspectorate, and the Regional Committee for Medical Research Ethics at Northern State Medical University, Arkhangelsk, Russia approved this study.

The Russian trawler samples were all male, while 56.8% of the Norwegian salmon workers were women. Demographic characteristics (age, smoking habits, BMI, education, etc.) were compared between male and female salmon-processing workers. No statistical differences were found. Therefore, to increase statistical power of the study, both women and men from the Norwegian study population were included in the statistical analyses (unless otherwise indicated).

Data collection

A modified version of the British Medical Research Council (BMRC) questionnaire was translated into Norwegian and Russian languages and has been used in earlier studies.[1,24] The two-part self-administered questionnaire included questions on socio-demographic, health, and occupational characteristics.

The first part contained questions on demographic data, smoking habits, and respiratory and allergic diseases. Asthma, allergies, eczema, and chronic obstructive pulmonary disease (COPD) were defined as adult-onset doctor-diagnosed disorders. Allergy to fish was defined as self-reported allergy to at least one type of fish (salmon, cod, herring, or other). Questions about family/childhood history of asthma and allergies were also included. The questions on general respiratory symptoms were defined as symptoms present in the last 12 months. Smoking status was categorized as never smoked (subjects, who never smoked regularly), former smokers (subjects who reported smoking regularly one or more cigarettes a day in the past), or current smokers (subjects who reported smoking regularly one or more cigarettes a day).

The second part of the questionnaire asked for symptoms that the subjects attributed directly to their work. All questions on work-related symptoms were limited to the last 12 months and defined as symptoms that were present during or immediately after working hours. Symptoms were divided into two groups: (1) upper respiratory symptoms: frequent sneezing, running nose, and sore throat; (2) lower respiratory symptoms: dry cough, cough with phlegm, wheezing, shortness of breath, and chest tightness.

The questionnaires included a question on self-evaluated causes of the work-related respiratory symptoms. Answer options included: (1) contact with fish, (2) contact with fish waste, (3) cold work environment, (4) contaminated indoor air, and (5) use of disinfectants.

Lung function measurements

Spirometry was undertaken using a Vitalograph-MDI compact 1 (Vitalograph Ltd., Buckingham, England). Our research group, in accordance with American Thoracic Society (ATS) guidelines, performed all the

tests. Age, height, and weight were recorded to calculate the percentage of predicted values for males and females separately. Tests were conducted with the subjects seated. Forced vital capacity (FVC) and forced expiratory volume in one second (FEV_1) were obtained by letting the person expire forcefully after a maximum inspiratory maneuver. Forced expiratory maneuvers were performed until satisfying the recommended criteria.[25] The highest values of FVC (l), FEV_1 (l/second), and FEV_1/FVC (%) were used in the analysis. Subjects with technically unsatisfactory spirometry were excluded from the analyses. Calculations of predicted values were based on equations proposed by Castellsague *et al.* for European origin populations.[26] Reduced lung function was characterized as FEV_1 and FVC less than 80% of predicted values. Airway obstruction was defined as FEV_1/FVC ratio below the fifth percentile of predicted values.

Fractional exhaled nitric oxide measurements

Fractional exhaled nitric oxide (FE_{NO}) was measured by chemoluminescence using an nitric oxide monitor (NIOX; Aerocrine AB, Solna, Sweden), according to 2005 ATS guidelines[27] and expressed in parts per billion (ppb). Subjects exhaled fully, and then inhaled ambient air through a nitric oxide scrubber to total lung capacity. Subjects then exhaled against an automatically adjusted resistance to achieve a constant exhalation flow rate of 50 ml/second. Resistance was adjusted so that an upper airway pressure of at least 5 cm H_2O was maintained throughout exhalation, sufficient to close the velum and exclude nasal air. Fractional exhaled nitric oxide measurements were taken from a stable plateau in exhaled nitric oxide concentration for at least 3 seconds during an exhalation. Any exhalation not meeting ATS/ERS requirements was rejected by the NIOX system. Gender and smoking influence FE_{NO} concentrations,[28] therefore statistical analyses were stratified by these two determinants. Statistical analysis was restricted to males. Spearman correlation analysis did not show significant results between age and FE_{NO} levels, therefore correction for age was omitted.

The study was carried out in Norway from November to April and in Russia between December and January to limit exposure to environmental pollen. Exclusion criterion was the presence of acute respiratory infection. We identified no participants with such infections.

Statistical analysis

Based on the distribution analysis, continuous variables were presented as mean (standard deviation/range) and categorical variables as number (percent). Fractional exhaled nitric oxide levels had skewed distribution, and therefore were presented as geometric mean (range) and analyzed with Mann–Whitney *U* test. Single variable analyses were performed with independent-samples *t*-test and Pearson Chi-square test. Multiple linear/logistic regression was used to analyze continuous/fixed parameters of spirometry between two groups after adjustment for age and smoking. Multiple logistic regression was applied to calculate the odds ratios (ORs) and 95% confidence intervals of respiratory symptoms between the two groups of workers, with adjustments for age and smoking history. Multiple logistic regression was also used to examine respiratory symptoms in relation to length of employment, adjusting for smoking history among trawler fishermen, and for smoking and gender among salmon workers. Spearman correlation analysis was applied to study associations between FE_{NO} levels, age, and height. Data were analyzed with SPSS software package (version 20.0 for Windows, Chicago, IL, USA). All tests were two-sided, *P* values <0.05 were considered to be statistically significant.

Results

Characteristics of the study population

The demographic features of the study population ($n=266$) are presented in Table 1. On average, salmon workers were younger than trawler fishermen, with 41.7% below the age of 35. Smoking status of participants was nearly even between the two groups and there were no significant differences with respect to mean BMI or duration of education. Length of employment was significantly longer among trawler fishermen when compared to salmon workers. The prevalence of asthma, allergies, and COPD did not differ significantly between the two groups, while higher percentage of salmon workers reported doctor-diagnosed eczema. Sixty percent asthmatic salmon workers and 20% of asthmatic trawler workers reported asthma in childhood. A total of 6.3% of trawler workers and 4.3% of salmon workers reported allergy to fish.

General and work-related respiratory symptoms

Prevalence of respiratory symptoms is presented in Table 2. No significant associations were found between gender and respiratory symptoms for salmon workers (adjusting for age and smoking), therefore data are presented for the whole study population. The prevalence of respiratory symptoms between trawler and salmon workers was significantly different. Salmon workers had significantly increased odds of shortness of breath with wheezing and prolonged cough, while trawler fishermen had significantly higher odds of work-related running nose and dry cough.

Analysis of work-related respiratory symptoms and length of employment

Multiple logistic regression was used to calculate the OR of respiratory symptoms in relation to length of employment. Results of the analysis showed elevated OR of work-related respiratory symptoms from

Table 1 Characteristics of the study population

	Salmon workers (*N*=139)	Trawler fishermen (*N*=127)	*P* value*
Age, years			
Mean (SD)	38.5 (11.7)	45.9 (9.9)	0.02
<35, *n* (%)	58 (41.7)	19 (15.0)	0.04
36–45, *n* (%)	41 (29.5)	33 (26.0)	0.03
46–55, *n* (%)	24 (17.3)	53 (41.7)	0.01
>56, *n* (%)	16 (11.5)	22 (17.3)	0.05
Smoking, *n* (%)			0.56
Current smokers	56 (40.3)	55 (43.3)	0.23
Former smokers	36 (25.9)	25 (19.7)	0.91
Never-smokers	47 (33.8)	47 (37.0)	
BMI, mean (SD)	25.5 (4.1)	26.1 (4.1)	0.34
Education, years	12.0 (2.3)	12.9 (2.5)	0.72
Length of employment, years			
Mean (range)	8.2 (1–33)	23.1 (1–47)	0.01
Asthma †, *n* (%)	10 (7.2)	5 (3.9)	0.13
In childhood,‡ *n* (% of asthma cases)	6 (60)	1[29]	n/a
Allergy†, *n* (%)	14 (10.1)	15 (11.8)	0.48
Allergy to fish,‡ *n* (%)	6 (4.3)	8 (6.3)	0.10
Eczema,† *n* (%)	12 (8.6)	1 (0.79)	n/a
COPD,† *n* (%)	5 (3.6)	3 (2.4)	0.27

SD: standard deviation; BMI: body mass index; COPD: chronic obstructive pulmonary disease.
*P value for Pearson Chi-square test (categorical variables), for independent-samples *t*-test (continuous variables).
†Adult onset, self-reported doctor-diagnosed.
‡Self-reported, n/a – not applicable (due to few cases among trawler workers).

upper airways in both groups of workers, with significant results found for frequent sneezing (OR=1.11 in salmon workers and OR=1.14 in trawler fishermen) and running nose (OR=1.15 in salmon workers and OR= 1.17 in trawler fishermen). No significant results were found for lower airways symptoms.

Self-evaluated causes of work-related respiratory symptoms

Self-evaluated causes of work-related respiratory symptoms were distributed similarly between the two groups of workers. ''Cold work environment'' was the most frequent reported cause (38.1–40.1%) of respiratory symptoms, followed by ''use of disinfectants'' (more common among salmon workers) and ''contaminated indoor air'' (equal for both groups). Pearson chi-square test found no significant differences between the groups (Table 3).

Among trawler fishermen and salmon workers who reported ''cold work environment'' as a causative factor for respiratory symptoms, running nose was the most frequent work-related symptom (69.2 and 50.1% respectively). Among salmon workers who reported ''use of disinfectants,'' frequent sneezing was the most commonly reported work-related symptom (62.5%).

Table 2 Prevalence *n* (%) and adjusted odds ratio (OR, 95% confidence interval) of general and work-related respiratory symptoms in salmon workers and trawler fishermen

	Salmon workers (*n*=139)	Trawler fishermen (*n*=127)	Adjusted OR (95% CI)*
General respiratory symptoms			
Wheezing	27 (19.4)	14 (11.0)	0.5 (−0.02–1.3)
Shortness of breath with wheezing	20 (14.4)	6 (4.7)	0.3 (0.01–0.9)†
Daily morning cough	51 (36.7)	41 (32.3)	1.1 (0.2–3.2)
Daily morning phlegm	25 (18.0)	28 (22.0)	1.2 (0.3–5.1)
Prolonged cough ‡	20 (14.4)	6 (4.7)	0.3 (0.04–0.8)†
Work-related respiratory symptoms			
Upper			
Frequent sneezing	16 (11.5)	13 (10.2)	1.02 (0.2–5.5)
Running nose	28 (20.1)	38 (29.9)	1.4 (1.03–5.9)†
Sore throat	14 (10.7)	8 (6.3)	0.8 (−0.2-(3.3))
Lower			
Dry cough	8 (5.7)	17 (13.4)	1.5 (1.02–6.4)†
Cough with phlegm	12 (8.6)	12 (9.4)	1.07 (0.06–7.6)
Wheezing	7 (5.0)	3 (2.4)	n/a
Shortness of breath	10 (7.2)	4 (3.1)	n/a
Chest tightness	6 (4.3)	3 (2.4)	n/a

*Odds ratio (95% confidence interval) of the symptoms adjusted for age and smoking by multiple logistic regression. Salmon workers (men and women) formed the reference category (OR=1.0).
†$P<0.05$, n/a – not applicable (due to few cases among trawler workers).
‡Daily cough that is lasting more than 3 months in the last 12 months.

Table 3 Self-evaluated causes of work-related respiratory symptoms, presented as number (%)

	Salmon workers *N*=139	Trawler fishermen *N*=127
Contact with fish	7 (5.0)	7 (5.5)
Contact with fish waste	5 (3.0)	3 (2.4)
Cold work environment	53 (38.1)	51 (40.1)
Contaminated indoor air	10 (7.2)	9 (7.1)
Use of disinfectants	20 (14.4)	10 (7.9)

Lung functions

The pulmonary function of study participants was compared to the predicted lung function for individuals of the same age, height, and gender (Table 4).[26] Both occupational groups had significantly lower FEV_1 and FVC than predicted. Thirteen salmon workers (16.4%) and 14 trawlers workers (11.5%) had FEV_1 lower than 80% of the predicted value. More trawler workers (18%) compared to salmon workers (13.9%) had FVC lower than 80% of predicted. In all, 5.1–5.7% had FEV_1/FVC less than fifth percentile of predicted. Multiple regression analysis showed no significant differences between the two groups.

Fractional exhaled nitric oxide levels

We stratified FE_{NO} measurements by smoking status and gender (Table 5). Overall, trawler fishermen had a larger range of FE_{NO} levels (5–108 ppb) than salmon workers (5–47 ppb). The highest mean levels in salmon workers were among former smokers (16.3 ppb for men and 13.1 ppb for women). For trawler fishermen, the highest mean levels of FE_{NO} were among never-smokers (17.2 ppb). Statistical analysis was only performed for males and showed significantly higher levels of FE_{NO} among trawler fishermen who never smoked compared to salmon workers.

Levels of FE_{NO} (geometric mean) were significantly higher among asthmatic trawler workers (28.1 ppb) compared to non-asthmatics trawler workers (12.4 ppb), while asthmatic salmon workers did not have significantly higher FE_{NO} levels (12.6 ppb) compared to salmon workers without asthma (10.9 ppb) (data not shown). Fractional exhaled nitric oxide levels in asthmatic trawler workers (28.1 ppb) and male salmon workers (12.6 ppb) showed a statistical significance ($P<0.05$, Mann–Whitney U test). A non-significant positive correlation was found between FE_{NO} levels, age, and height.

Discussion

We found that seafood workers exhibited a high prevalence of respiratory symptoms and poor performance on lung function tests.[1–13] In this study, we compared two groups of seafood workers engaged in line processing at offshore factory trawlers and onshore factories. Questionnaire, spirometry, and measurements of FE_{NO} were utilized to explore respiratory outcomes in the two worker groups and to better understand possible explanatory factors involved in the development of respiratory outcomes in the workers.

General respiratory symptoms over the last 12 months differed between salmon and trawler workers. Salmon workers showed a higher prevalence of shortness of breath with wheezing and prolonged cough compared to trawler workers. This may indicate a strong influence of obstructive characteristics of respiratory symptoms, suggesting that the salmon workers could have asthma – COPD – like conditions. This was, however, not confirmed by a high prevalence of diagnosed asthma or COPD in salmon workers. It may be that the questions on asthma and COPD diagnoses in our study were not sufficiently sensitive, as a positive outcome depended on the prior physician visit and diagnostic testing. Thus, additional undiagnosed cases may have been present in both study groups.

A 7.2% prevalence of asthma among salmon workers is consistent with previously reported asthma prevalence of 8 and 7.6% in two different salmon worker populations.[1,5] Asthma prevalence among trawler workers was 3.9% and is consistent with

Table 4 Lung function values

	Salmon workers *N*=79	Trawler fishermen *N*=127
FEV_1% of predicted*	95.4 (13.7)‡	96.1 (16.2)‡
FVC% of predicted*	96.5 (16.4)‡	95.3 (14.9)‡
FEV_1/FVC%*	84.8 (8.9)	84.4 (11.6)
FEV_1 <80% of predicted†	13 (16.4)	14 (11.5)
FVC <80% of predicted†	11 (13.9)	22 (18.0)
FEV_1/FVC <5th percentile of predicted	4 (5.1)	7 (5.7)

*Presented as mean (standard deviation).
†Presented as number (percent).
‡$0.01<P<0.05$, one-sample t-test, difference from 100%.
FEV_1: forced expiratory volume in one second; FVC: forced vital capacity.

previously reported asthma prevalence of between 2 and 8% in workers processing bony fish, irrespective of industry type.[19] Work-related COPD has previously been described in occupational environments where bioaerosols are an important exposure.[30–32] The finding of 3.6 and 2.4% COPD in salmon and trawler workers, respectively, is comparable to the finding of Jeebhay *et al.* stating that 3% of workers in the South African salt fish industry had symptoms suggestive of chronic bronchitis.[13]

Results from spirometric tests show that both salmon workers and trawler workers had mean levels of FEV_1 and FVC below 100% of predicted values. No difference was found between the two seafood worker populations when comparing FEV_1 and FVC results. A FEV_1/FVC less than fifth percentile of predicted is indicative of a COPD. There were no differences between the two worker groups in the percentage of workers exhibiting spirometric test results indicative of COPD. The higher prevalence of symptoms of lower airway obstruction was thus not reflected in differences between the groups in spirometric results, but the results indicate that lung function is impaired in both worker groups.

Comparing FE_{NO} levels between the two groups of seafood workers, we found significantly higher FE_{NO} levels among never-smoking trawler workers compared to never-smoking salmon workers. Further analysis revealed that asthmatic trawler workers had substantially higher FE_{NO} levels compared to asthmatic salmon workers (males). Fractional exhaled nitric oxide is thought to reflect eosinophilic inflammation[33–35] and behaves as a biomarker of "allergic asthma" phenotype rather than asthma itself. The higher FE_{NO} levels in trawler workers could accordingly point to a greater influence of allergic mechanisms among these workers. The lower levels of FE_{NO} as well as low prevalence of specific salmon IgE[22] may thus point to higher influence from non-allergic mechanisms and less 'allergic type' asthma in salmon workers. However, the low numbers of diagnosed asthmatics in both groups and the lack of IgE-data in trawler workers prevent strong conclusions.

Results showed that childhood asthma was reported more often by asthmatic salmon workers compared to asthmatic trawler workers. This may suggest a greater influence of predisposition in salmon workers than in trawler workers; however, due to the small number of asthma cases in both populations, the data must be interpreted with caution.

Dry cough is a common symptom of airway irritation and is often associated with asthma, irrespective of allergic or non-allergic in origin. Also, rhinorrea may be due to allergy or non-allergic irritation and is known to be associated with and often precede asthma.[36,37] Previous research in the South African salt water fish industry showed that 26% of the workers had naso-ocular symptoms – of which 2.6% had allergic type rhinoconjunctivitis.[13] In our study, 10% of salmon workers and 12% of trawler workers reported adult onset allergy, while only 4.3 and 6.3% reported a fish allergy, respectively. Therefore, it seems likely that most cases of rhinorrea in our study are explained by irritative rather than allergic effects.

Exposures in the work environments may reflect differences in symptom reporting. The positive association between length of employment and work-related frequent sneezing and running nose in both worker groups indicates an effect of work environmental factors and no prominent healthy worker effect for these symptoms. It has been established that breathing cold air is associated with airway symptoms. Both salmon and the trawler workers rated "cold environment" to be the most important explanatory factor for their airway symptoms. The most common short-term respiratory effects of low temperatures are rhinorrhea, nasal congestion, sneezing, and cough.[14,38] Approximately 50% of healthy and allergic subjects report cold-air-induced rhinorrhea.[39] We have previously shown that running nose and cough are associated with feeling cold at seafood industry workplaces.[24] In the present study, mean temperature levels of different workplaces in salmon industry varied between 6.6 and 15.0°C (unpublished data). Thermal conditions are expected to offer even greater challenges for trawler workers as they perform regular outdoor work tasks in harsh climatic conditions. In addition, open

Table 5 Nitric oxide concentration in ppb (presented as geometric mean (range)) stratified by smoking

	Salmon workers			
	Men, $n=31$	Women, $n=45$	Total, $n=76$	Trawler fishermen, $n=127$
Current smokers	11.1 (5–34)	8.1 (5–19)	9.3 (5–34)	9.5 (5–46)
Former smokers	16.3 (7–33)	13.1 (5–47)	14.2 (5–47)	15.8 (5–108)
Never-smokers	11.5 (8–18)	10.7 (6–21)	11.0 (6–21)	17.2 (7–47)*
Total	12.4 (5–34)	9.9 (5–47)	10.8 (5–47)	12.6 (5–108)

* $P<0.05$, Mann–Whitney U test, difference in fractional exhaled nitric oxide (FE_{NO}) levels between never-smokers salmon workers (men) and trawler fish-processing workers.

hatchways during loading and the presence of only partly shielded block freezers in the production area also contribute to low temperatures in indoor areas. The relatively high prevalence of running nose and dry cough may point to a greater influence of low temperatures among trawler workers compared to salmon workers.

Workers ranked the use of disinfectants as the second most frequent cause of respiratory symptoms. Chlorine compounds, quaternary ammonium compounds, and peroxygen compounds are commonly used disinfecting agents,[40] often in the form of foams that are sprayed over the total production area prior to washing/rinsing by high pressure water. In the salmon industry, special cleaning workers with respiratory protective equipment normally perform this process at night. However, the salmon workers may be exposed to the remnants of the chemical agents in workplace air, especially in early morning hours. On fish trawling vessels, the fisherman themselves are typically responsible for disinfection. Therefore, trawler workers may be directly exposed to disinfectants. The use of disinfection chemicals in food industry has been linked to irritative airway effects, and there are also reports on disinfectants functioning as adjuvants in allergic type asthma.[20,21] In our study, the salmon workers who reported "use of disinfectants" as a cause of respiratory symptoms had significantly higher prevalence of frequent sneezing. Whether differences in exposure to disinfection agents may contribute to the differences in airway symptom patterns between trawler and salmon workers needs to be further explored.

Almost equal percentage of workers from both groups ranked "contaminated indoor air" as the third most frequent cause for work-related respiratory symptoms. Due to the formulation of the question, it is not possible for us to know workers' definition of "contaminated air." The finding, however, shows that workers associate indoor air pollution with reported work-related respiratory symptoms.

Levels and composition of bioaerosols are expected to be different in the salmon industry and on board factory trawlers. In trawlers, various species of fish (cod, haddock, flounder, pollock, halibuts, etc.) are processed, as opposed to the salmon industry where only salmon is processed.

Seafood processing on ships offers special challenges. Confined production areas with sparse ventilation may result in high concentrations of airborne contaminants. Findings from the crab industry show that exposure levels of allergens were considerably higher on board of crab-processing vessels as compared to the levels measured at an onshore crab processing plant.[12,41] The indications of more allergic-type asthma from the results of FE_{NO} tests could thus be a consequence of higher allergen concentration in the trawler factory processing areas, however. further studies including allergen exposure measurements combined with allergy testing of the workers are needed to confirm this.

Other factors, not related to workplace exposures, may be of importance to the prevalence of airway symptoms in the two seafood worker populations. The populations differ in nationality, culture, gender composition, age distributions, length of employment, and recruitment procedures, all of which may impact symptoms. The influence of age and smoking were corrected for in the multiple regression models and spirometric tests. We cannot exclude that FE_{NO} levels are subject to population/genetic based differences. Genetic differences in FE_{NO} levels have been previously described.[42] Cultural differences are difficult to adjust for and we cannot exclude their influence in questionnaire data. However, we find it likely that cultural differences would affect all questions on respiratory symptoms in the same direction, and accordingly unlikely that such differences would have major impact on symptom patterns depicting the relative frequency of some symptoms as compared to other symptoms. The recruitment of the two worker populations was different and may have had impact on the results. Whereas the salmon workers were recruited with the help of the factory management, the trawler workers were recruited during annual health examinations. Length of employment was significantly lower in salmon workers.

During our visits to salmon factories, several workers told us that some of the workers had to be moved to administration from processing facilities because of symptoms caused by difficult working conditions. Although we do not have information on this beyond the anecdotal, prospective research would be of interest.

The two groups of seafood workers were examined in two different time periods and exposure levels may not have been constant through the total period. However, neither workplace underwent drastic changes that might affect exposure levels during the 2 year period of data collections.

In conclusion, the present study shows different respiratory symptom patterns between two groups of seafood workers: Russian trawler factory workers and Norwegian salmon industry workers. We found more obstructive type respiratory symptoms in salmon workers and more nasal symptoms and dry cough in trawler workers. Exposure to low ambient temperatures, disinfection agents, and bioaerosols in the two seafood workplaces is discussed. There is a need for more extensive studies on workplace exposures onboard trawlers and more detailed physiological and laboratory tests in workers from both onshore and offshore fish processing facilities.

Disclaimer Statements

Contributors None.

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Conflicts of interest None.

Ethics approval The survey was approved by the Regional Committee for Medical Research Ethics in Northern Norway and the Norwegian Data Inspectorate as well as Regional Committee for Medical Research Ethics at Northern State Medical University, Arkhangelsk, Russia.

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