Trawler fuel exhaust and respiratory impairments: a cross-sectional pilot study among Indian fishermen working in informal sectors

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Background: An estimated half a billion people are engaged in fishing related occupations in India. Exposure to adulterated fuel exhaust is common among deep-sea fishermen, yet little is known about the potential impacts on the exposure to health.

Objective: The aim of this study was to investigate whether fuel emission exposure was associated with increased respiratory impairments among fishermen who were occupationally exposed to fuel exhaust compared to fisherman occupationally unexposed to fuel exhaust.

Methods: This cross-sectional study compared the prevalence of respiratory symptoms and lung function variables between 152 marine-water and 107 fresh water fishermen considering the use of fuel-driven trawlers. Data were obtained from questionnaires and computerized spirometer.

Results: Fishermen exposed to trawler fuel exhaust reported more than double the number of respiratory symptoms compared to the unexposed fisherman (86.2 vs. 40.2%). They also had a significantly higher chance experiencing chronic cough (adjusted OR=3.51, 95% confidence interval (CI)=2.09–6.35), chronic phlegm (8.61, 4.76–15.97), and wheezing (4.29, 2.55–7.61) symptoms. Finally, there was a significant reduction of the ratio of mid portion of forced expiratory flow rate and forced vital capacity (FEF_{25-75}/FVC) in the exposed fishermen compared to the unexposed (0.84 vs. 0.73 second^{-1} , $P=0.015$).

Conclusion: Fuel exhaust may negatively impact on the respiratory health of Indian fishermen. More attention and surveillance of occupational health for fishermen in India is needed.

Keywords: Fishermen, Lung function, Occupational exposure, Respiratory symptoms, Trawler fuel

Introduction

In India, an estimated half a billion people are engaged in fishing related occupations, making it one of the largest industries in the country. However, many fishermen in India are part of the informal economy and commonly work in dangerous conditions with little or no occupational protections.

There are two primary types of fishing vessels used in India: hand-driven man-powered small boats used in canals and rivers, and sub-mechanized power-driven wooden boats (trawlers) used in the sea. Marine fishermen typically sail in the deep sea without proper safety measures and/or sanitation, and lack protective equipment and global positioning systems

(GPS) on the boats. Exposure to indoor air pollutants is also an occupational health concern for fishermen on trawlers. Owing to financial constraints, most fishermen use non-refined diesel for the diesel-powered engines. However, this adulterated form of diesel contains a mixture of numerous compounds, including: naptha, kerosene, and volatile hydrocarbons, emitting air pollutants hazardous to respiratory health and exposing fishermen.

Recent research has highlighted the deleterious effects of automobile exhaust and indoor air pollution on respiratory health and it has been well established that the combustion of fossil fuels attribute to a wide variety of respiratory problems including asthma, chronic obstructive pulmonary disorder (COPD), and even lung cancer.^{1–15} Additionally, fuel adulterants such as naphtha, *n*-butanol, and kerosene, found in the

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adulterated trawler diesel, are known threats to human health. Past studies investigating the respiratory health of fishermen have found mixed results about health outcomes and have not focused on the identification of specific exposures.¹⁶ Furthermore, the fishing industry on the Indian sub-continent is largely a sole proprietorship venture, and therefore is not regulated by occupational health norms.

This study hypothesized that fisherman exposed to trawler fuel exhaust have increased risk of adverse respiratory health symptoms compared to fisherman not occupationally exposed to trawler fuel exhaust. This study is the first of its kind to report the symptomatic and physiological impairments in the respiratory health of Indian fishermen exposed to trawler fuel smoke. The study also adds to the scant literature on the occupational health of fishermen.

Methods

Study design

We performed a cross-sectional study with Indian fishermen who were dependent on fishing as their primary source of income. To test our hypothesis, fishermen who operated mechanized fuel-driven boats (exposed) and hand-driven boats (unexposed) were recruited. In order to be eligible, the fishermen could not be engaged in other employment outside of fishing or use both mechanized and hand-driven boats during the course of their work. Therefore, the unexposed fishermen were not occupationally exposed to trawler fuel exhaust and sailed in the sea. Likewise, the exposed fisherman did not use hand-driven boats and sailed on freshwater.

We identified five fishing harbors adjacent to the Bay of Bengal (depot for sea fishes) and ten harbors adjacent to Jalangi and the Ganges Rivers (depot for fresh water fishes) as potential study locations. From these harbors, we randomly selected six; two sea fishing harbors (adjacent to the Bay of Bengal) and four fresh water harbors (adjacent to the Ganges and Jalangi Rivers).

Data collection took place between October and December 2011. Potential participants learned about the study from the Fisherman Welfare Organization. All participants provided informed consent form before data collection. This study was approved by the Departmental Research Committee of the Department of Physiology, University of Kalyani and was conducted according to the norms of the Declaration of Helsinki.

Interested fishermen were asked to attend a local clinic where data collection was performed. Approximately 350 fishermen were approached and 293 agreed to participate in the study. All participants were male. Fishermen were excluded if they were unable to perform spirometry or unwilling to complete

the questionnaire. After exclusion, 259 (88% of the fishermen who initially agreed to participate) were included in the study: 152 fishermen (mean age 58 ± 9.8 years) who used fuel-driven mechanized boats (exposed) and 107 fishermen (mean age 53 ± 10.3 years) who used manually powered boats (unexposed). Recruitment criteria are provided in Fig. 1.

Questionnaire assessment

We used a pre-validated Bengali version of the European Community Respiratory Health Survey (ECRHS II) questionnaire, which contained questions about lifestyle, exposure pattern (exposure to adulterated diesel exhaust), and general health of the participants.¹⁷ To subjectively assess respiratory health, participants were asked if they had experienced any of the following symptoms in the previous 12 months: prolonged cough, chronic phlegm, morning cough with sputum, acute or chronic wheezing or whistling in chest, breathing trouble, nasal allergy, and/or a runny or stuffed nose.

Lung function

Lung function was measured using a computerized spirometer (POP-10, Maestros Mediline Systems Limited, Mumbai, India). The system had a pneumotach (a pressure sensor) in the mouthpiece that quantifies the force of pressure during expiration. The software uses a standard formula to quantify lung function based on different lung volumes. The formula for the predictive lung volumes differs according to various standards, race, and anthropological factors. All tests were performed according to the guidelines of the American Thoracic Society [ATS 1994], using the best of three values for forced vital capacity (FVC), forced expiratory volume at 1 second (FEV₁), forced expiratory flow rate (FEF_{25-75%}), and the ratio of FEF_{25-75%} and FVC.¹⁸ Before data collection, the instrument was adjusted according to published Indian standards for the predicted values of FVC, FEV₁, and FEF_{25-75%}.¹⁹ An FEV₁/FVC ratio of 0.7 defined airway obstruction. The instrument was calibrated prior to the tests with a 3-l fixed volume calibration syringe. The quality of each spirogram was evaluated for acceptability and repeatability in accordance with the ATS/ERS (1994) statement.¹⁸ To achieve accurate and replicable spirometry, each participant completed between three and eight spirometry maneuvers.

Assessment of heat index (HI)

Heat index information was acquired from meteorological offices adjacent to the study areas. We obtained temperature (°C) and relative humidity (%) data from 1 January to 31 December 2011. Mean values of the maximum and minimum temperature and humidity were obtained for each day. The relative humidity and ambient temperature were

Figure 1 Flow chart of the study design.

used to construct the HI, which represents the human-perceived equivalent temperature. The National Oceanic and Atmospheric Administration (NOAA) nomogram was used to determine the HI, according to the following formula:²⁰

$$\begin{aligned} \text{Index}_{\text{heat}} (\text{HI}) = & -42.379 + (2.04901523 \times T) \\ & + (10.14333127 \times \text{rh}) - (0.22475541 \times T \times \text{rh}) \\ & - (6.83783 \times 10^{-3} \times T^2) - (5.481717 \times 10^{-2} \times \text{rh}^2) \\ & + (1.22874 \times 10^{-3} \times T^2 \times \text{rh}) + (8.5282 \times 10^{-4} \times T \times \text{rh}^2) \\ & - (1.99 \times 10^{-6} \times T^2 \times \text{rh}^2) \end{aligned}$$

Where, T represents temperature and rh represents relative humidity of an area. Values of heat indices were calculated in degree Celsius ($^{\circ}\text{C}$).

Data analysis

Chi-square and unpaired t -tests were used to test for differences in baseline characteristics between the

exposed and unexposed groups and one-way ANOVA tested for statistically significant differences in spirometric data between the two groups. Multiple logistic regression analysis was performed to test the association between exposure to trawler exhaust and respiratory symptom-based outcomes. 95% confidence intervals (CI) were calculated for all Mantel-Haenszel odds ratios (OR), and a P -value of 0.05 was used for all tests of significance. The models were controlled for age, job experience, average daily working hours, heat indices, parental asthma, smoking status, and regular exposure to second hand smoke (SHS) at home and/or at work. All analyses were performed in SPSS versus 20.

Results

Baseline characteristics of the study participants are presented in Table 1. Although the exposed fishermen

Table 1 Baseline characteristics of study participants

Characteristics	Unexposed fishermen (N=107)	Exposed fishermen (N=152)	P-value
Age (years)	53 (10.3)	58 (9.8)	0.041
Height (m)	1.71 (0.23)	1.70 (0.17)	0.76
Body mass index (kg/m ²)	20.18 (3.17)	21.12 (4.61)	0.45
Job experience (years)	27.3 (7.3)	29.2 (4.7)	0.37
Average daily working hours (hours)	10.4 (2.7)	13.4 (3.4)	0.038
Ever smoker	31 (28.9)	41 (26.9)	0.83
Parental asthma	4 (3.7)	8 (5.3)	0.78
Regular exposure to SHS	58 (54.2)	101 (66.4)	0.06
Workplace HI (°C)	28.42 (8.93)	36.08 (8.46)	0.027

*Data shown as mean (SD) or *n* (%) unless otherwise indicated.

†Ever smoker: ever smokers were defined as those who reported having smoked >100 cigarettes during their lifetime.

‡SHS: second hand smoke; HI: heat index.

§Level of significance was considered as probability, $P < 0.05$.

were older than the unexposed fishermen ($P=0.041$), there was no statistically significant difference between the groups' smoking habits, family history of asthma, and history of exposure to SHS. Exposed fishermen had a greater average daily working time ($P=0.038$) compared to the unexposed. The workplace HI was significantly ($P=0.027$) higher for the exposed fishermen compared to the unexposed fisherman.

Table 2 shows the prevalence of respiratory symptoms among study participants. The trawler fuel exhaust exposed fishermen had a significantly higher prevalence of respiratory problems compared to the unexposed fishermen (OR 9.13, 95% CI 5.09–16.04). After taking into account the differences in age, job experience, average daily working hours, HI, parental asthma, smoking status, and regular exposure to SHS at home and/or at work, the exposed fishermen still had a significantly higher prevalence of prolonged cough, chronic phlegm production, morning cough with sputum, wheezing/whistling in chest, and trouble breathing when compared to the unexposed fishermen. Occurrences of nasal allergy and associated symptoms did not significantly differ between the two groups (nasal allergy and runny/blocked nose: OR=1.27, $P=0.61$ and OR=1.17, $P=0.79$, respectively).

Lung function test results are presented in Table 3. For fishermen exposed to trawler fuel exhaust, we observed a decrease in lung function. There was a fall

in FEV₁ of approximately 6% among the exposed fishermen compared to the unexposed fishermen. There was also a significant reduction of FEV₁/FVC among the exposed fishermen compared to the unexposed fishermen ($P=0.04$). We found a profound decrement of FEF_{25–75%} among exposed workers, of nearly 500 ml/second and 12% for its predicted percentage, compared to the unexposed. There was also a highly significant mean deficit of FEF_{25–75%}/FVC ($P=0.015$) for the exposed fishermen, possibly because of the chronic exposure to adulterated fuel exhaust.

Calculated HI values for the study sites are presented in Fig. 2. Coastal/sea regions had a consistently higher HI compared to inland regions. HI remained at higher than 30°C for over 8 months of the year in the coastal areas.

Discussion

We observed a significantly higher prevalence of respiratory symptoms and delineated lung function among fishermen exposed to trawler fuel emissions compared to fishermen who were not occupationally exposed to trawler fuel emissions. It is our hypothesis that reduced lung function and enhanced breathing-associated troubles is likely because of the occupational exposure to inhalable fuel emissions from the diesel-powered trawler engines. However, additional factors such as environmental conditions and work

Table 2 Occurrence of respiratory symptoms among study participants

Symptoms	Unexposed (N=107)	Exposed (N=152)	OR (95% CI)
Any respiratory symptom	43 (40.2)	131 (86.2)	9.13 (5.09–16.04)
Prolonged cough	24 (22.4)	78 (51.3)	3.51 (2.09–6.35)
Chronic phlegm	18 (16.8)	97 (63.8)	8.61 (4.76–15.97)
Morning cough with sputum	27 (25.2)	82 (53.9)	3.26 (2.02–5.96)
Wheezing or whistling in chest	26 (24.3)	89 (58.5)	4.29 (2.55–7.61)
Breathing trouble	21 (19.6)	72 (47.4)	3.47 (2.08–6.54)
Nasal allergy	12 (11.2)	21 (13.8)	1.21 (0.59–2.70)
Runny or blocked nose	11 (10.3)	18 (11.8)	1.09 (0.53–2.59)

*Data shown as *n* (%).

†Odds ratios (ORs) (referents being the control group, OR=1) were adjusted for age, job experience, average daily working hours, HIs, parental asthma, smoking status, and regular exposure to second hand smoke (SHS) at home and/or at work.

‡The values do not add up to 100% because of multiple non-exclusive responses.

Figure 2 Pattern of month-wise heat index (HI) for the entire year in the riverside and coastal areas where the study was conducted.

patterns may also be contributing factors to the observed differences. Compared to the unexposed fishermen, the exposed fishermen experienced higher prevalence of respiratory problems. One contributing factor may be that exposed fishermen frequently wear wet clothing over long periods of time. Wearing wet clothes for a prolonged period lowers the body temperature, causing hypothermia and potentially exposing workers to being cold.²¹ Common cold can have an impact on the respiratory system. Previous studies have shown that hypothermia may compromise the immune system and can lead to an increased risk of infection, especially in the respiratory tract. These infections may lead to more adverse conditions such as bronchitis and pneumonia.^{22,23} This study also found that the exposed fishermen had a higher prevalence of chronic phlegm and chronic cough symptoms, likely exacerbated by exposure to fuel emissions and other associated factors like higher HI, common cold, and respiratory tract infection. The findings of aggravated respiratory symptoms among fishermen exposed to trawler fuel exhaust are similar to a study by Shiryayeva *et al.*, which found higher prevalence of chronic cough and chronic phlegm among a group of trawler fishermen.¹⁶ The probability of aggravated respiratory symptoms as an indirect effect of dampness of the indoor environment

has been supported by previous studies where researchers have found that higher relative humidity in the indoor environment helps in the growth of fungus and allergenic mites, which in turn cause respiratory tract infection.^{24–27}

We found a moderate change in the percentage predicted values of FEV₁ and profound change of FEF_{25–75} in the exposed fishermen compared to the unexposed fisherman. This finding is similar to prior research that found reduced mid expiratory flow rates among trawler fishermen.¹⁶ Our findings also suggest that although there was no variation in the forced vital capacity between the two groups, there was a significant drop in the FEF_{25–75}/FVC ratio in the exposed fishermen, indicating obstruction in the lower respiratory tract.^{28–30}

The major limitation of this study was that fuel emissions and particles in the exhaust were not measured. The trawler boats lack the necessary power supply to support the equipment for these measurements and exposed fishermen remain in the deep sea for up to 20 days at a time. The indoor conditions on the boats are wet and humid and it would be logistically challenging to install air samplers. Another limitation of this study was its cross-sectional design, which provides no temporal information about the relationship between exposures and symptoms. Although a longitudinal and systematic approach to investigate the pulmonary health of fishermen would be more informative, this study provides baseline information about the delineated respiratory health of Indian fishermen. This study is the first of its kind to measure respiratory function among Indian sea fisherman and provides a starting point for future studies. A bronchodilator was not used because of logistic issues and thus reversibility was not tested. However, this did not influence the initial findings of spirometry and participants' self-reported symptoms added substantially to the understanding of the pulmonary health status of the fisherman. Although we believe that fuel exhaust was likely the principal factor for the prevalence of pulmonary problems, other exposures,

Table 3 Lung function of the study participants based on exposure to adulterated fuel exhaust

Parameters	Unexposed (N=107)	Exposed (N=152)	P-value
FVC (l)	3.35 ± 0.51	3.17 ± 0.27	0.23
FEV ₁ (l)	2.74 ± 0.41	2.56 ± 0.25	0.04
FVC (% pred)	86.28 ± 16.27	83.55 ± 18.29	0.14
FEV ₁ (% pred)	82.34 ± 11.38	76.23 ± 12.56	0.03
FEV ₁ /FVC	0.93 ± 0.13	0.88 ± 0.11	0.04
FEF _{25–75%} (l/second)	2.82 ± 0.41	2.32 ± 0.23	0.01
FEF _{25–75%} (% pred)	87.23 ± 16.23	75.48 ± 13.27	0.012
FEF _{25–75%} /FVC (second ⁻¹)	0.84 ± 0.16	0.73 ± 0.21	0.015

*Data shown as mean ± SD.

†FVC: forced vital capacity; FEV₁: forced expiratory volume in 1 second; FEF_{25–75%}: forced expiratory flow rate of 25–75% of the FVC.

‡Level of significance was considered as $P < 0.05$.

including prolonged working hours, unfavorable working environments, and personal health cannot be ignored. The strength of this study was the inclusion of several and diverse fishing harbors in order to minimize the selection bias. In general, the study provides insight into the health risks among fisherman in India.

In conclusion, we found a delineating respiratory health among the fishermen exposed to trawler fuel exhaust. The exposed fishermen experienced a higher chance of respiratory symptoms including chronic phlegm, prolonged cough and breathing trouble, and also had lower lung function compared to the other group of fishermen who never had exposure to fuel exhausts of the fishing boat. These findings provide an important insight into the high probability of unregulated occupational exposure and respiratory diseases, especially among the workers of informal sectors.

In developing countries, unorganized sectors are largely excluded from social, economical, and medical services and the health of workers is largely ignored. In India, more than half a billion people are engaged in the occupation of fishing, the majority of who belong to the informal sector. Although the workers contribute significantly to the economy of the country, there is hardly any attempt to look after their social, economical and health concerns. Further, lack of knowledge about proper material handling and safety aspects also jeopardize the health conditions of the workers of the informal sectors. This report highlights only one area of concern, namely the poor respiratory functions of Indian fishermen that are part of a much larger problem. We recommend immediate and robust surveillance of occupational health for fishermen in India.

Disclaimer statements

Contributors SM: Designed the study, collected, analyzed, and interpreted data, and wrote the manuscript.

SGM, PH, and AKP: Collected data and wrote the manuscript.

SS: Analyzed data, wrote the manuscript, supervised the study, and took final decision for submission.

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Ethics approval The study was approved by the Departmental Research Committee of the Department of Physiology of the University of Kalyani. The study was performed according to the guidelines of the Declaration of Helsinki.

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