Saudi Journal of Biological Sciences 27 (2020) 985–990

Contents lists available at ScienceDirect

Saudi Journal of Biological Sciences

journal homepage: www.sciencedirect.com

Original article

Occupational exposure and respiratory health of workers at small scale industries

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ARTICLE INFO

Article history:
Received 29 October 2019
Revised 15 January 2020
Accepted 16 January 2020
Available online 27 January 2020

Keywords:
FVC
FEV1
Occupations
Pulmonary functions
Respiratory health

ABSTRACT

Certain occupations like welding, painting, and vehicle repairing are associated with regular exposure to dust, exhausts, fuels, fumes, PM, and vapors of welding, solvents, and paint. Many studies have proved a reduction in lung functions due to exposure to these agents. The present study aims to assess and compare respiratory symptoms and pulmonary functions among exposed and non-exposed persons as well as suggests controls respectively. A cross-sectional case study was carried out among small scale industry workers having matched demographic and anthropometric parameters. Medical Research Council (MRC) questionnaire and Micro Direct computerized automated spirometer were used for recording respiratory ailments and pulmonary function tests (PFT) respectively. The percentages of mechanics, welders and painters were 40.9, 31.8, and 27.3 respectively. The highest reported respiratory symptom was chest tightness and whistling among exposed (22.7%) and unexposed (10%). Among study exposed cases, the occupational exposure was found as often (22.7%), sometimes (68.2%) and never (9.1%) while the reported use of airway protection (masks) was very low. Overall respiratory health of the exposed versus controls was reported as excellent (54.5% vs 73.4%), good (27.3% vs 23.3%) and average (18.2% vs 3.3%) respectively. The exposed group on contrary to control one has decreased mean values for FEV1 (3.12 vs 3.50), FVC (4.12 vs 4.43), FEV1/ FVC % (79.60 vs 80.79) and PEF (414.77 vs 523.16). The present study reveals that exposed workers are at increased risk of developing respiratory symptoms and decreased pulmonary functions as compared to unexposed. Such exposure research studies are instrumental in health status evaluation of workers. However, this area has been neglected by the researchers in Saudi Arabia. It is, thus, strongly recommended to carry out prospective studies to substantiate the study results including large sample size, background pollutants concentrations and biological monitoring. Control strategies should be adopted to reduce the vapor concentration in the ambient air, protect and promote respiratory health of workers.

1. Introduction and literature review

Rapid urbanization, automobiles and industrial activities give rise to urban air pollution dominated by oxides of sulphur (SOx), nitrogen (NOx), carbon (COx), volatile organic compounds (VOCs) and suspended particular matter (SPM) in all cities of the world (Chawla and Lavania 2008). In urban areas certain occupations like welding, painting, vehicle repairing and servicing are associated with exposure to fumes, vapors, gases, exhausts, dust, and SPM. Jeddah is the vehicle dominate city, having many associated small scale industries where workers are regularly exposed such job related exposures (Ahmad et al., 2016). Urban air pollution has health effects on the public as well as on workers specially those working in traffic congested environment and road side small-scale industries. Vehicular exhaust is the worst type of exhaust as it is emitted at the ground near the breathing level, and it gives maximum human exposure (Ahmad et al., 2017). Respiratory health problems like pulmonary functions reductions due to such working exposures are relatively unexplored area of research (Aprajita and Sharma, 2011; Spengler et al., 2011).

Respiratory disorders range from deterioration of pulmonary function, dryness of the throat, coughing, tightness in the chest,

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Peer review under responsibility of King Saud University.

Production and hosting by Elsevier

https://doi.org/10.1016/j.sjbs.2020.01.019
1319-562X/

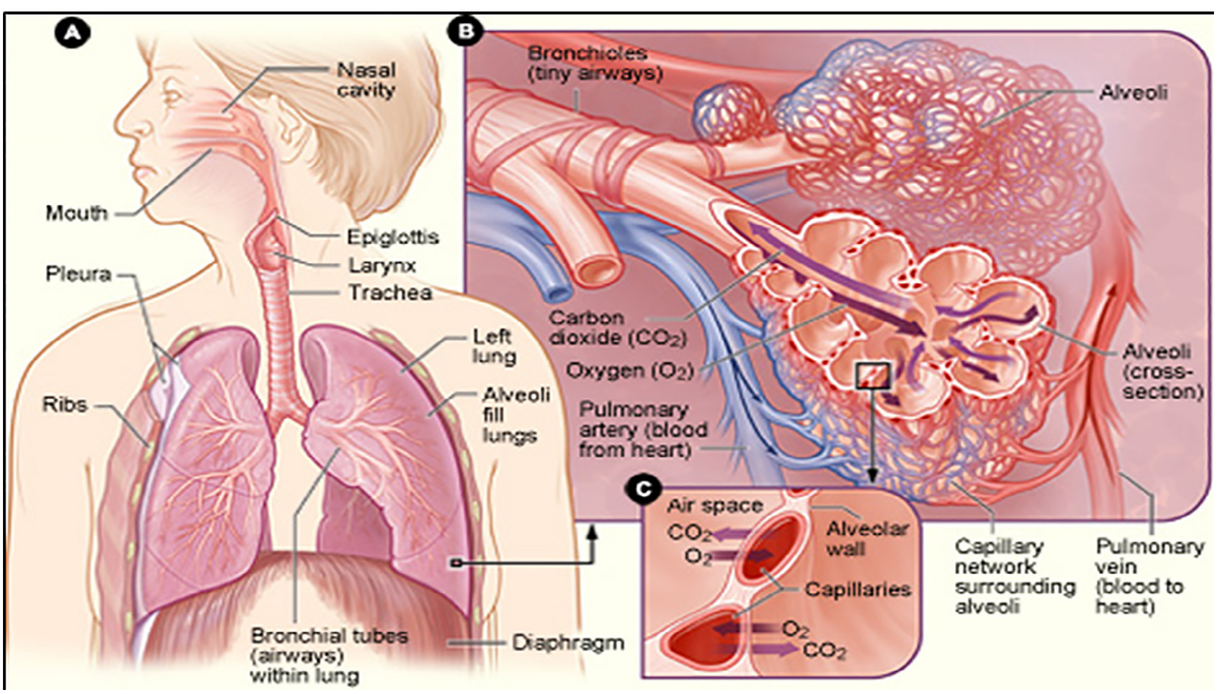
wheezing, and breathlessness to chronic bronchitis and metal fume fever (Al-Otaibi, 2014). Some studies report a 30–40% greater incidence of lung tumors among workers exposed to welding fumes. Roadside small workshops workers are regularly exposed to fuels, used gasoline oils, solvents, paints, dust, SPM, gaseous fumes and vapors of welding (Brosseau et al., 2014) with minimum protective measures that can minimize skin cancer risk and respiratory ailments (Kamal et al., 2011; Ahmad et al., 2017; Balkhyour et al., 2018). Exposure to petroleum products among certain occupations for a long time significantly effects respiratory systems and the symptoms such as breathlessness, chronic cough, and wheezing can be observed (Uzma et al., 2008; Anuja et al., 2014). Moreover, if the exposure concentration is higher there will be the chance of marked systemic pulmonary inflammatory response.

The inhaled air at small workshops near traffic congested areas contains SOx, NOx, COx, VOCs, and SPM. These pollutants adversely affect respiratory health of workers. The fuel exhausts released the particles which are extremely fine having large surface area and can transport high rate of toxic compounds including metals and hydrocarbons on their surface. These fine particles are capable of longer retention and have a probability to deposit in greater numbers and deep into the lungs (Wichmann, 2007; Anuja et al., 2014). COx and SOx can cause multitude adverse effects on a respiratory system like tissue hypoxia, reversible decrease in functions of lung, constriction of the bronchioles, severe airways obstruction, pulmonary edema and hypoxemia, while NO2 impairs the immune defense mechanisms of lungs.

Solid particulate matter (SPM) generated in emissions gets attached with soot particles and enters into the lungs on exposure which increase the risk of malignancies and pneumoconiosis. Working with different petroleum fuels, exhausts, solvents, paints is associated with high risk of respiratory problems depending on the task performed and the duration of exposure. A Study by Kesavachandran et al. (2006) showed that petroleum evaporates more readily in hot than cold countries so in the local prevailing environmental and meteorological conditions of Jeddah the respiratory health of the studied population can be at greater risk.

Human lungs functionality is evaluated by pulmonary function testing and the main type of PFT is spirometry (Harbison, 2013). Spirometry is performed by spirometers, these are the devices which employ noninvasive diagnostic techniques for testing and screening of lung functions. These are relatively cheaper and, perform within minutes. As the lungs diseases, i.e. bronchitis, emphysema and asthma are prevailing and common, spirometry have become an indispensable technique in epidemiology, clinical, and occupational settings, as well as in industrial medicine (Harbison, 2013).

Spirometry is the most commonly executed PFT and have a substantial role in the diagnosis of lungs abnormalities and categorizing their severity (Harbison, 2013; Sood et al., 2007). Basic spirometry tests data provide an important database for the health care physicians and occupational health specialist. Spirometry is a medical screening test which helps in evaluating lungs functions among humans (Miguel, 2012; Harbison, 2013). For overall human health, the balance between supply and quantity of oxygen to human cells to function properly is very important (Miguel, 2012). The respiratory system consists of tissues and organs and help individuals to breathe, its main parts are lungs, airways, blood vessels, and muscles supporting breathing as shown in figure.



This research study aimed at identifying respiratory symptoms and pulmonary functions testing among small industry workers in comparison to a non-exposed control group. This study can be used as a benchmark which could lead to the determination of the magnitude of the respiratory health problems and associated factors among small industry workers at a larger scale in Jeddah. The findings of this study are important in addressing, prevention and control of respiratory ailments factors among not only in studied population but among other industrial workers in Jeddah as well. The results of the study are also of importance to suppliers, workshop workers, managers, OSH institutions and to policymakers. It is also a basis for safeguarding the public health in the country at large.

2. Methodology

2.1. Design and sampling

The study was carried out among 312 randomly selected small industry workers. Cross-sectional comparative study design was used in which the workplace exposure and health effects were recorded at the same time while comparing between exposed and non-exposed groups. The respondents were recruited by mix sampling methods and design (simple random sampling, purposive sampling, referral by suppliers and drivers etc.). The inclusion criteria were age range between 18 and 50 years, no past history of chronic lung disease and kidney failure and at least 1 year working experience on the current job. Informed consent was obtained from all recruited volunteers after the aim and objectives of the study were briefed to all participants (Ahmad et al., 2017; Al-Otaibi, 2014; Balkhyour et al., 2018). Participants were communicated that they were free, regarding their withdrawal from the study and were also taken in confidence for privacy of their personal information's.

A descriptive sample of different categories of workers with varying exposure time from 162 small body repairing, welding and painting workshops. Office workers like clerks, cleaners, drivers and managers having none exposure to welding, fuels and paints with matched age, demographics, height, etc. were included for minimizing healthy worker effects biasness. (Balkhyour et al., 2018). Many other studies have documented similar methodologies and study protocols for conducting exposure and human health studies (Al-Otaibi, 2014; Adei et al., 2011; Ahmad et al., 2017). This research study, ethical approval was sought from Faculty of Meteorology and Environment as well as from King Abdulaziz University Hospital Medical Ethics Committee.

2.2. Questionnaire and anthropometric measurements

During survey and interview a pre standardized and validated questionnaire was filled for all participants in their native language. The questions related to respiratory health were derived from Medical Research Council (MRC) standard questionnaire (MRC, 1976; Cotes and Chinn, 2007). In order to minimize biasness different questions were arranged and phrased in a proper sequence and recorded in the answers sheet. Along with sociodemographic, personal, anthropometric, respiratory health, description of different types of occupational exposures their magnitude were also recorded. The height (centimeters), weight (kgs) and Body Mass Index (BMI) were noted by their respective tape, weighing balance and Quetelet's index.

2.3. Pulmonary function tests

The study participants were first introduced regarding the spirometer principal, operation and procedure for carrying lungs function testing (LFT). The data of subjects like age, date of testing, height, name and weight were recorded in the spirometer. LFT by spirometer was carried out by following guidelines of American Thoracic Society (ALA, 2012). LFT was recorded in the office of workshops during work hours by the automated computerized spirometer of Micro Direct company (model mL 3500S). Participant's permission and any possible contraindications to LFT was considered before the start of spirometry. The spirometry was conducted in standing position by wearing nose clip while the subjects taking full inspiration and rapid forceful expiration in the mouthpiece of instrument. The weak and invalid inspiration and expiration efforts were not included. Different LFTs assessment variation sources like effort, position of subject, effort etc. were possibly controlled.

For every subject three spirometry readings were taken and the best reading amongst the three was selected. A variation of <5 was considered as the final reading. In order to minimize inter investigator variability only one investigator recorded and performed all subjects interviews and LFT. After strictly following inclusion criteria 162 working exposed cases and 150 unexposed control subjects were finally selected. FVC (forced vital capacity), FEV1 (forced expiratory volume in 1 sec), PEFR (peak expiratory flow rate in liters/sec and FEV1/FVC were noted in automated spirometer following all standards protocols (Kesavachandran et al., 2006; Adei et al., 2011). The spirograms in the form of printouts were directly downloaded from the spirometer and data was recorded in excel sheets. In order to assess and evaluate workers respiratory health the recorded LFT readings from spirograms, and self-reported respiratory health symptoms from questionnaire were compared.

2.4. Statistical analysis

Data were checked and entered into a personal laptop on daily basis, it was analyzed by using Statistical Packages for Social Sciences (SPSS) version 20. Statistical procedures like basic descriptive, frequency distribution, chi-square (χ^2) test with risk estimate was employed for socio-demographic and respiratory health symptoms questions analysis. Max, mean, min, and standard deviation were calculated for lung function parameters, a p-value of 0.05 or less was assumed for statistical significance.

3. Results and discussion

3.1. Demographics and personal variables

The number of exposed workers was 162 while that of unexposed controls was 150. Both groups were males having matched characteristics in terms of age, height, weight, BMI, job duration, education and smoking habits. The percentage of exposed mechanics, welders and painters was 40.9, 31.8, and 27.3 respectively. Mean age (y) of the exposed and unexposed was 30.8 ± 8.4 and 31.2 ± 5.8 respectively. 9.1% of the exposed and 20% of the controls were local residents while all others were expatriates from different countries like Pakistan, India, Yemen, and Turkey. Among exposed 18.2% were having no formal education, 40.9% had primary, 27.3% had middle while 13.6 had secondary education in comparison to the control group where 56.7% were having secondary and 33.3% were having college level education.

The average height (cm), weight (kg) and BMI (kg/m^2) of the exposed cases were 176.9 ± 8.8, 79.4 ± 8.8 and 22.9 ± 2.9respec tively while for control group these were 175.4 ± 6.4, 79.8 ± 9.1 and 23.3 ± 2.9 respectively. The single and married among exposed were 27.3% and 72.7% respectively while among control group they were 40% and 60%. The mean job experience was 7.0 ± 4.3 and 7.8 ± 1.3 years for exposed and controls respectively. It was, therefore, apparent that the two groups (exposed and controls) were comparable in terms of age, gender, ethnic origin and duration of work (Table 1).

3.2. Respiratory health symptoms and occupational variables

Smoking is regarded an important risk factor in causing lungs ailments, 40.9% exposed and 26.7% non-exposed subjects were reportedly smokers respectively. The prevalence rate of chest tightness among exposed and non-exposed was 22.7% and 10%

Table 1
Sociodemographic Characteristics of the cohorts.

Sociodemographic Characteristics		Exposed (%)	Unexposed (%)
Job Type	Mechanic	40.9	
	Welder	31.8	
	Painter	27.3	
	Control	–	100
Residence Status	Expatriate	90.9	80.0
	Local resident	9.1	20.0
Education level	No	18.2	0
	Primary	40.9	0
	Middle	27.3	10
	Secondary	13.6	56.7
	College	0.0	33.3
Marital Status	Single	27.3	40
	Married	72.7	60
Experience years (mean ± S.D)	7.0 ± 4.3		7.8 ± 1.3
Age year (mean ± S.D)	30.8 ± 8.4		31.2 ± 5.8
Height cm (mean ± S.D)	176.9 ± 8.8		175.4 ± 6.4
Weight kg (mean ± S.D)	79.4 ± 8.8		79.8 ± 9.1
BMI kg/m^2 (mean ± S.D)	22.9 ± 2.9		23.3 ± 2.9

respectively. Whistling and wheezing were reported by 13.6% exposed and 6.7% non-exposed while 22.7% cases and 10% controls reported nasal/throat irritation. The rate of frequent sneezing was 18.2 and 6.7% among cases and controls respectively. Shortness of breath and cough (for as long as three months) was reported by 13.6 and 9.1% cases while among controls nobody reported these two symptoms. Phlegm bringing up from the chest was reported by 13.6% cases and 10% control subjects. None among both groups declared past family history of respiratory ailments (Table 2).

Among study exposed cases the occupational exposure was found as often (22.7%), sometimes (68.2%) and never (9.1%) while the reported use of airway protection (masks) was as always (13.6%), sometimes (40.9%) and never (45.5%). Overall respiratory health of exposed group was reported as excellent (54.5%), good (27.3%) and average (18.2) while the control group reported excellent (73.4%), good (23.3%) and average (3.3%) (Table 2).

3.3. Pulmonary functions parameters

Table 3 displays different PFT observed values i.e. FEV1, FVC, FEV1/ FVC and PEF for both exposed and control study groups. The exposed group on contrary to control one has decreased mean values for FEV1 L (3.12 vs 3.50), FVC L (4.12 vs 4.43), FEV1/ FVC % (79.60 vs 80.79) and PEF L (414.77 vs 523.16). No statistical significant difference could be established among all these compared FEV1 ($p = 0.20$), FVC ($p = 0.23$), FEV1/ FVC ($p = 0.16$) and PEF ($p = 0.17$) values between both groups.

3.4. Discussion

This study points out that there is a reduction in PFT parameters among the exposed workers although no statistically significant difference was found for FVC, FEV1, PEF, FVC /FEV1 parameters. This statistical insignificant difference could be linked to the smaller sample size (Al-Otaibi, 2014). The decreased PFT values in the exposed group can be possibly linked to their daily routine workplace exposures like fumes, gases, fuels, dust, exhausts, and SPM which is absent among the unexposed control study cohorts. Some other studies also have reported impaired pulmonary functions due to welding exposures among the exposed study groups (Meo, 2003; Harbison, 2013; Ozdemir et al., 1995). Reduction in pulmonary functions among exposed selected occupations as compared to the control groups can be ascribed due to the exposure to high-level of fumes and vapors of fuels and solvents that can cause well defined systemic pulmonary inflammation.

The decrease in FVC, FEV1 among exposed cases can be due to the restrictive type of lungs disease, these findings were also observed by other studies (Kesavachandran et al., 2006; Begum and Rathna, 2012). The decreased values of pulmonary functions may indicate underlying lung dysfunction due to polluted air inhalation caused by automobile exhaust and fuel vapors (Choudhari et al., 2013). Vehicular emissions and movements account for some 60–70% of total air pollution containing many pollutants (VOCs, SPM, NOx, COx & SOx). These pollutants are emitted at breathing level causing more harm for occupations who use to take such contaminated air for respiration at small-scale industries (Choudhari et al., 2013). The other contributing factors toward decreased values of pulmonary functions in the present study could be sedentary life style, housing at the job sites (as many interviewed workers use to live at their workshops and continually exposed to workplace exposures round the clock), smoking and dietary habits.

An increased risk of reported respiratory symptoms like chest tightness, wheezing or whistling in the chest, nasal/throat irritation, sneezing, shortness of breath, chronic cough, phlegm from chest were found to be higher among the exposed study group than the control group. But the statistically significant difference could be established for chest tightness and breath shortness

Table 2
Respiratory health problems of the cohorts.

Respiratory health problems		Exposed (%)	Unexposed (%)	P
Chest tightness (breathlessness)		22.7	10.0	0.16
Wheezing or whistling in chest		13.6	6.7	0.25
Nasal/throat irritation		22.7	10.0	0.25
Frequent sneezing		18.2	6.7	0.10
Shortness of breath		13.6	0	0.09
Cough for as long as three months		9.1	0	0.19
Phlegm from chest		13.6	10	0.22
History of respiratory ailment		0	0	–
Exposure to fumes, vapors, fuels and paints	Often	22.7	0	–
	Sometimes	68.2	0	–
	Never	9.1	100	–
Overall respiratory health	Excellent	54.5	73.4	0.17
	Good	27.3	23.3	0.29
	Average	18.2	3.3	0.04
Smoking	Yes	40.9	26.7	–
Airway protection	Always	13.6	0	–
	Sometime	40.9	0	–
	Never	45.5	100	–

Table 3
Pulmonary Function parameters among exposed and unexposed cohorts.

Pulmonary function Parameters	Exposed Mean ± SD		Unexposed Mean ± SD		P
	Observed	Predicted	Observed	Predicted	
FEV1 (L)	3.12 ± 0.5	3.7 ± 0.4	3.50 ± 0.4	4.0 ± 0.2	0.20
FVC (L)	4.12 ± 0.6	4.6 ± 0.5	4.43 ± 0.6	4.6 ± 0.6	0.23
FEV1/ FVC	79.60 ± 14.3	80 ± 12.4	80.79 ± 6.6	84 ± 7.1	0.16
PEF (L)	414.77 ± 88.7	538 ± 89.2	523.16 ± 84.0	589 ± 91.1	0.17

among both studied groups. The statistically insignificant differences for some of the respiratory complaints could be linked to the small sample size of the study. Similar respiratory health symptoms are cited by many studies to be common among exposed population due to workplace exposures (Balkhyour and Goknil, 2010; Loukzadeh et al., 2009; Harbison, 2013). Vehicular exhaust and other enhaled pollutants at studied workplaces can easily diffuse deeply in lungs resulting in lung damage including many respiratory ailments like chest tightness, nasal/throat irritation, sneezing, chronic cough and asthma (Vlachokostas et al., 2013; Souza et al., 1998). Moreover, exposure to SPM causes many respiratory symptoms as it works carrier for hydrocarbons on their surfaces and stays for long times. Air pollutants emission due to traffic exhaust and movements are further aggregated especially here in local conditions of Jeddah where air movement is low and no rain for prolonged periods of the year as well the meteorological conditions aggravate this further. This scenario makes the respiratory health of the selected workers further at increased risk.

The selected exposed workers at small industries are exposed to vapors and fumes of fuels; VOCs from paints; fillers and solvents; isocyanates and hexavalent chromium from spray painting operations; silica from sandblasting operations; dusts from sanding; and metal fumes from welding and cutting. These exposures would lead to chronic inflammation of respiratory system, leading eventually, to a significant decrease in lung functions and mechanical properties of breathing in the form of restrictive pattern (Balkhyour and Goknil, 2010). Different size PM generated by sanding, grinding and welding operations affects the respiratory system and produce impairment especially particulates big than 10μ held in the upper respiratory tract (Choudhari et al., 2013). Also, PM of the size of 2.5μ has been found to accumulate in the lungs and significantly associated with reduced pulmonary functions like FVC, FEV and, FEV1. Similar effects of automobile exhausts on the FVC and FEV have been reported in tunnel and bridge workers & traffic police (Evans et al., 1988). FEF is considered a fairly good test to identify early small airway diseases. The reported findings of the present study that exposed workers are at increased risk of developing respiratory symptoms are in agreement with most studies on respiratory ailments and decreased pulmonary functions due to respired polluted air (Choudhari et al., 2013; Vlachokostas et al., 2013).

4. Conclusion

This research study highlights adverse effects of workplace exposures on respiratory health and impairment of the pulmonary functions among welders, painters and auto mechanics. The study reveals decreased lung functions among the exposed subjects as compared to the unexposed controls. The exposed workers are highly vulnerable for developing respiratory health symptoms and pulmonary function impairment. The highest reported respiratory symptoms were chest tightness and whistling among exposed group. Among study exposed cases the occupational exposure was found as often (22.7%), sometimes (68.2%) and never (9.1%) while the reported use of airway protection (masks) was very low. The overall respiratory health of the exposed versus controls was reported as excellent (54.5% vs 73.4%), good (27.3% vs 23.3%) and average (18.2% vs 3.3%) respectively. The exposed group on contrary to control one has decreased mean values for FEV1 (3.12 vs 3.50), FVC (4.12L vs 4.43), FEV1/ FVC % (79.60 vs 80.79) and PEF (414.77 vs 523.16).

The studied small industry workers are among more vulnerable occupational groups due to deficiency of resources, unsafe working conditions, lack of education, training and awareness, lack of regular monitoring and inspections and non-availability or use of personal protective gadgets. Interventional plans like education, awareness, good sleep, proper use safe tools and PPEs, regular medical checkups should be advocated for workers. This study will provide the baseline for further elaborative studies and control strategies to protect and promote the respiratory health of the studied population in future. Local authorities like Jeddah municipality, ministry of labor, civil defense, and Saudi General Organization for Social Insurance (GOSI) should be involved for extending occupational health facilities and other social protection services like basic sanitation, easy access to wash rooms, drinking water, sheds, waste disposal, first aid, provision of PPEs, medical and social insurance etc.

5. Study limitations

We could not get the ambient air quality background environmental readings at the studied locations, hence the quantification of the workplace exposures could not be commented on. It was also not possible to carry out urine analysis for the metabolites of benzene and toluene to indicate the magnitude of fuel vapors inhalation in the subjects studied. As with other cross-sectional studies, this study is susceptible to survivor bias because it assessed prevalence rather than incident cases. There is a possibility that individuals with symptoms were more willing to participate than those without symptoms, therefore, the subject selection was not truly random.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgement

This study was funded by the Deanship of Scientific Research (DSR) at King Abdulaziz University, Jeddah, Saudi Arabia. The authors, acknowledge with thanks DSR for technical and financial support. The authors thank and appreciate all the small-scale industry workers, managers, supervisors, and owners for being part of this study.

This manuscript "Occupational exposure and Respiratory health of workers at small scale industries" is original, and is a part of corresponding author own PhD dissertation entitled "Occupational Health and Safety in Selected Small Industries in Jeddah and Strate-

gies to Improve it" submitted to King-Abdulaziz University Scientific Publishing Centre in 2018. No part of the manuscript has been published before, nor is any part of it under consideration for publication at another journal.

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