Original Article

Assessment of the lung function status of the goldsmiths working in an unorganized sector of India

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ABSTRACT

Context: Exposure to various types of fumes and gases are very common in Jewelery industries. No Report is available regarding the effects of those fumes and gases on the respiratory functions of the goldsmiths. Due to lack of proper monitoring of the workplace environments in these unorganized sectors, workers get very much affected by the occupational exposures to those irritants. **Aims:** The present study aimed to investigate whether the occupational exposures to fumes and gases might alter the lung functions of the goldsmiths. **Materials and Methods:** A total of 118 goldsmiths and 66 unexposed control subjects were taken randomly for the study. The goldsmiths were further classified in 3 groups according to duration (year) of exposures in the work environment, ETA_1 (less than 5 years), ETA_2 (more than 5 years but less than 10 years), and ETA_3 (more than 10 years). Peak expiratory flow rates (PEFR), forced vital capacity (FVC), and forced expiratory flow rates of different intervals ($FEF_{25\%}$, $FEF_{50\%}$, $FEF_{75\%}$, $FEF_{25-75\%}$) were measured using computerized Spirometer (Maestros Mediline, India). The statistical analyses were carried out using Minitab software version 3. **Results:** Lung functions of the goldsmiths significantly ($P < 0.01$) decreased from that of the control group. Inter-group comparison also showed the deteriorations of lung functions was associated with exposure time, and more exposed workers had significantly less ($P < 0.01$) efficiencies of lung functions. **Conclusions:** Workplace fumes and gases were responsible for deterioration of the lung function status of the goldsmiths.

KEY WORDS: Lung function, fumes, metals

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INTRODUCTION

Occupation-induced respiratory disturbances have been reported in many studies.[1-5] But, apart from the study of Murgia *et al.*,[6] no study was reported, which could show the occupation-induced physiological changes, especially respiratory changes amongst the goldsmiths. Some reports showed that the mortality rates of the workers of jewelery industries increased due to cancer.[7,8] Reports stated that continuous exposure to acidic air and nitrogen and sulfur oxides can cause carcinogenicity in the lung tissues.[9-17] But, no study has been reported, which could highlight the occupation-induced respiratory hazards of the goldsmiths in India, especially in the unorganized sectors.

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MATERIALS AND METHODS

Study population

A total of 184 subjects were taken in the study. Amongst them, 118 were goldsmiths who have been engaged in the jewelery industries for at least 1 year. According to experience in that particular sector, they were categorized in 3 subgroups; exposure having less than 5 years (ETA_1), more than 5 years but less than 10 years (ETA_2) and more than 10 years (ETA_3). 66 persons were taken as a reference group for subjective analysis purpose. They were mainly the storekeepers, managers, and front desk office workers of the same industry. The Departmental Research Committee of the University of Kalyani approved the study, and all subjects signed written consent form before participating in the study. All the reference subjects were non-smokers, and only 11 of the goldsmiths were smokers.

Measurement of physiological profiles

Height (in cm) and weight (in kg) of the subjects were measured using anthropometric rod and weighing machine, respectively. Body mass index (BMI) was calculated from height and weight according to the method of Weisell.[18]

Questionnaire study

A slightly modified ECRHS (European Community Respiratory Health Survey) questionnaire was applied to the subjects for the assessment of respiratory disturbances.[19] The questionnaires were translated into regional languages for easy communications and were translated back to English to validate the outcomes.

Spirometry

A computerized Spirometer (Maestros Mediline Systems Limited, India) was used to assess the respiratory health of the participants. Guidelines of the American Thoracic Society (ATS) and European Respiratory Society (ERS) were followed during spirometry. All the participants were thoroughly informed about the processes of spirometric tests. Forced vital capacity (FVC) and forced expiratory flows of 4 intervals ($FEF_{25\%}$, $FEF_{50\%}$, $FEF_{75\%}$, and $FEF_{25\text{-}75\%}$) of the subjects were measured. Peak expiratory flow rate was measured using Peak expiratory flow meter (Medicare Equipments, India). Every test for each participant was performed 3 times, and the best value was taken. The values of forced vital capacity and forced expiratory flow of different percentages were expressed as the percentage of their respective predicted values.

Assessment of the components of workplace fumes and gases

Concentrations of sulfur oxides (SOx), nitrogen oxides (NOx), suspended particulate matters (SPM), carbon monoxide (CO), and carbon dioxide (CO_2) of the workplaces were measured using a portable air monitoring kit (LaMotte, USA). Those concentrations were compared with the maximum limiting values proposed by the Pollution Control Board of the Government of West Bengal.[20]

Statistical analyses

One-way ANOVA was used to analyze the effect of exposure of the goldsmiths in respect of each of the study variables from that of the reference group. To observe the patterns of changes of the lung functions due to exposure duration, one-way ANOVA was performed. Odd ratio was performed to observe whether the outcomes of respiratory disturbances of the goldsmiths differed from that of the reference group. As the percent predicted value of $FEF_{25\text{-}75\%,}$ PEFR and FVC were reported to be more crucial marker for detection of lung functions over the other study variables ($FEF_{25\%}$, $FEF_{50\%}$, $FEF_{75\%}$), regression analyses of those 3 study variables (PEFR, FVC, and percent predicted value of $FEF_{25\text{-}75\%}$) were performed taking time of exposure as predictor to observe whether the predictor had any influence on the changes of those study variables. Two-tailed levels of significance were taken as $P < 0.01$ for all variables under study, and Minitab version 3 (USA) was used for the analysis purpose.

RESULTS

The mean values of age, height, weight, and body mass index (BMI) were presented in Table 1. There were no significant differences between the mean ages of the workers and the subjects of the control group, and there were not much deviation of the other physiological variables like height, weight, and BMI.

In Table 2, the levels of concentrations of different components of the workplace fumes were presented. The ranges of those pollutants vary according to seasonal and occasional changes. When there is a huge demand of ornaments, especially during festivals or social occasions, the work load increases and also the workplace environment changes.

The values of PEFR, FVC, $FEF_{25\%}$, $FEF_{50\%}$, $FEF_{75\%}$, and $FEF_{25\text{-}75\%}$ were compared between the reference group and the goldsmiths using one-way ANOVA and are presented in Table 3. It can be observed that the *F* values of each of the variables decreased in the exposed group from the reference group.

One-way ANOVA of the different exposed groups (ETA_1, ETA_2, and ETA_3) was presented in Table 4, and the results showed that the changes of the variables were significant between the groups. It can be said that the changes of the pulmonary variables were due to exposure to the hazardous work environment as constant exposure to that environment deteriorated the pulmonary health of the workers. The patterns of changes of the variables were dependent on the exposure duration as more exposed workers had lower levels of PEFR, FVC, $FEF_{25\%}$, $FEF_{50\%}$, $FEF_{75\%}$, and $FEF_{25\%\text{-}75\%}$ compared to that of the less exposed workers. The results showed that the workers having

Table 1: Mean Age, height, weight, and body mass index (BMI) between the control and exposed groups

Variables	Control (*n* = 66)	Exposure		
		ETA_1 (*n* = 28)	ETA_2 (*n* = 34)	ETA_3 (*n* = 56)
Age (Years)	35.24±3.40	32.85±4.52	35.42±2.42	35.46±3.16
Height (cm)	168.28±9.56	171.15±10.56	168.56±6.45	170.51±7.56
Weight (Kg)	60.75±5.29	62.43±4.96	61.05±4.25	62.56±3.54
BMI (kg/m^2)	23.34±2.81	23.42±1.86	22.38±2.37	23.69±3.24

Values shown are Mean ± SD

Table 2: Assessment of different components of the workplace air

Components	Range at workplace
Oxides of sulfur (SOx)	118.4-140.3 μg/m^3
Oxides of nitrogen (NOx)	102.4-128.2 μg/m^3
Suspended particulate matters (SPM)	69.3-100.2 μg/m^3
Carbon monoxide (CO)	0.72-0.98 mg/m^3
Carbon dioxide (CO_2)	0.01-0.02 mg/m^3

Table 3: Comparison of spirometric values between goldsmiths (exposed) and the reference (unexposed) groups (*n* = 184)

Variables	Control	Goldsmiths	*F* value	*P* value
PEFR (L/Sec)	458.18±4.18	314.24±49.79	223.38	< 0.01
FVC (% Pred)	95.49±5.50	83.22±5.66	198.92	< 0.01
$FEF_{25\%}$ (% Pred)	83.91±1.41	54.57±12.61	167.97	< 0.01
$FEF_{50\%}$ (% Pred)	144.17±3.19	109.67±19.43	69.08	< 0.01
$FEF_{75\%}$ (% Pred)	270.34±7.91	192.85±38.52	77.32	< 0.01
$FEF_{25-75\%}$ (% Pred)	153.67±3.82	92.22±24.18	167.92	< 0.01

Overall difference is based on one-way ANOVA, $P < 0.01$. *F* values in ANOVA are significant at $P < 0.01$

exposure less than 5 years (ETA_1) had better lung functions than the workers having exposure more than 5 years and more than 10 years (ETA_2 and ETA_3). As the duration of exposure increased, the lung functions decreased.

The outcomes of the respiratory disturbances of the exposed and unexposed subjects were analyzed using odds ratio, and the results showed that the positive outcomes were much higher ($P < 0.01$) in the exposed group than that of the unexposed counterpart [Table 5].

Regression analysis of PEFR, FVC, and $FEF_{25-75\%}$ with the duration exposure as predictor showed that more deterioration of that study variable was influenced by the predictor, and the influence was significant. The patterns of changes of those study variables were nearly same as the duration of exposure increased. Changes of PEFR, ($r = -0.819$, $P < 0.001$), FVC ($r = -0.81$, $P < 0.001$), and $FEF_{25-75\%}$ ($r = -0.80$, $P < 0.001$) were presented [Figure 1a-c].

DISCUSSION

In the present context, particularly in Indian perspectives, as there are huge numbers of unorganized sectors, assessment of workers' health is somewhat impossible neither the quality of the work environment can be tested. Lack of proper knowledge about workplace environment makes the workers affected more and the tendency of work-related injuries and accident increases.

The assessment of workplace fumes indicated that there were apparently higher concentrations of SOx and NOx than the proposed limit in the workplaces. According to the proposed permissible exposure levels of the Pollution Control Board of the Government of West Bengal, the concentrations of SOx and NOx were higher in the workplaces than the recommended values (PEL for SOx- 60 μg/m^3; PEL for NOx- 60 μg/m^3).[20] Sulfuric and nitric acids when come in contact with high temperature and various metals, various oxides of sulfur and nitrogen are produced in gaseous forms and as those acids and fumes are very hygroscopic, they produce mists in the workplaces. The concentration of SPM was less in the workplaces (PEL: SPM- 140 μg/m^3) because those places were free from dusts and other associated particles. Carbon monoxide, which is produced during incomplete combustion of carbon, was also much less in the manufacturing sectors (PEL: 2 mg/m^3) although a very small amount of coal is used in those units.

Data reported that decrease in forced expiratory flow could diagnose reduced pulmonary efficiencies, and it was also reported that altered value $FEF_{25-75\%}$ could be a marker for identifying obstructive type lung diseases. According to the results, peak expiratory flow rate and forced expiratory flow of different percentages decreased significantly ($P < 0.01$) with the exposure duration. In recent days, the concept of vital capacity no longer exists, and concept of measuring forced vital capacity has come.

The fumes of various metals, acids, and gases were associated with the deterioration of the pulmonary efficiencies of the goldsmiths, and the results obtained were similar with that of the findings of other authors.[16] In this study, the mean ages of the workers were not related with the differences of exposures because the workers of more exposure joined the industry at very young ages and the workers with less exposure joined the industry relatively later. As there were no significant differences in ages and the body mass indices between the workers and the control subjects, it could be stated that the alterations of the pulmonary variables were neither mediated by malnutrition nor by age of the workers. Assessment of the secondary exposures of the total study population revealed that there were no significant risk factors, which could lead to malfunction of the respiratory system of the workers. Apart from the work stress, no factor was observed, which could make any influence over the normal functions of the lung. So, a clear conception can be obtained that secondary exposures were not much associated with the altered outcomes of lung function tests.

The inter-group analyses showed that the alteration of respiratory indices were dependent upon the duration of exposure to the hazardous fumes and gases. As the exposure increased, the tendency of respiratory obstructions also increased. The study found that a total of 56 goldsmiths had percent predicted values of $FEF_{25-75\%}$ lower than 70% of the predicted and amongst them, 12 were suspected to be suffered from airways obstructions. Chattopadhyay *et al.*[2] showed that constant exposure to fumes and gaseous pollutants were associated with reduced forced vital capacity and peak expiratory flow rates, which could cause an alteration of respiratory health. The validity of assessment of PEFR over the other standard PFT (Pulmonary Function Test) indices lies in the context that the other indices (e.g. FEV_1) are more sensitive in assessing bronchoconstriction of the

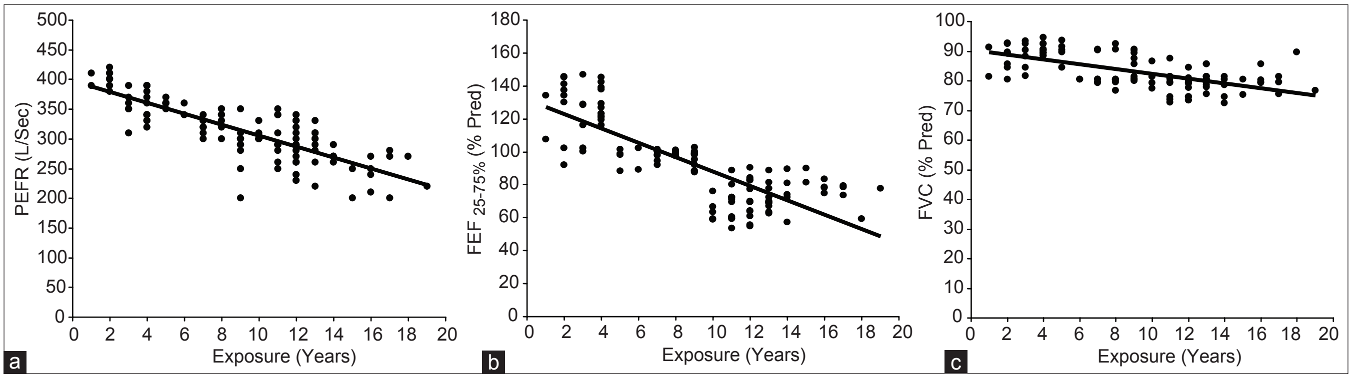

Figure 1: (a) Linear regression of PEFR with the durations of exposures. The durations of exposures and PEFR values of the goldsmiths (n = 118) were pooled, and the analysis was performed by taking PEFR and exposure durations as study variable and predictor respectively (95% CI: -0.87-0.75). (b) Linear regression of FVC (% Pred) with the durations of exposures. The durations of exposures and percent predicted values of FVC of the goldsmiths were pooled, and the analysis was performed by taking FVC (% Pred) and exposure durations as study variable and predictor respectively (95% CI: -0.73-0.51). (c) Linear regression of FEF25-75% (% Pred) with the durations of exposures. The durations of exposures and percent predicted values of FEF25-75% of the goldsmiths were pooled, and the analysis was performed by taking FEF25-75% (% Pred) and exposure durations as study variable and predictor respectively (95% CI: -0.88-0.73)

Table 4: Inter-group comparison of spirometric values of the goldsmiths according to the duration of exposure (years)

Variables	Goldsmiths (*n* = 118)			*F* value	*P* value
	ETA_1 (*n* = 28)	ETA_2 (*n* = 34)	ETA_3 (*n* = 56)		
PEFR (L/Sec)	372.14±5.80	319.41±6.01	282.14±4.82	63.72	< 0.01
FVC (% Pred)	89.07±3.69	84.19±5.14	80.18±4.47	49.82	< 0.01
$FEF_{25\%}$ (% Pred)	69.95±2.10	53.68±1.66	47.43±0.937	60.03	< 0.01
$FEF_{50\%}$ (% Pred)	129.30±3.19	112.19±2.04	98.32±2.10	40.35	< 0.01
$FEF_{75\%}$ (% Pred)	229.34±6.53	209.93±4.30	164.23±2.99	66.41	< 0.01
$FEF_{25-75\%}$ (% Pred)	126.40±2.88	97.13±0.752	72.16±1.33	261.57	< 0.01

Data are presented as the respective *F* values for the analysis of variance for each variable. The *F* values of the ANOVA are significant at $P < 0.01$

Table 5: Outcome of the secondary exposure to respiratory hazards of the total study group

Respiratory symptoms	Positive outcome		Odd ratio	95% CI
	Control (*n* = 66)	Goldsmiths (*n* = 118)		
Chronic cough	4	26	4.38*	1.45-13.17
Sneezing	8	40	3.72*	1.62-8.54
Whistling	2	11	3.29*	0.71-15.31
Breathing trouble	2	23	7.75*	1.76-34.00

*Values of the ORs are significant at $P < 0.01$

airways while PEFR can be an effective measure for home monitoring of lung function,[21] and Litonjua *et al.*[22] showed that $FEF_{25-75\%}$ could be an effective way to identify the pulmonary health, and alteration of $FEF_{25-75\%}$ was associated with obstructive types of pulmonary diseases.

Alteration of peak expiratory flow rates showed significant changes with the duration of exposure, and the results were similar with that of the percent predicted values of forced expiratory flow rates of 25-75%. For long-term exposure to the polluted environment, the lung tissues of the goldsmiths faced great challenge as cytotoxicity due to fumes and gases could alter the proportionate growth of the lung tissues. Sheel *et al.*[23] launched a term "dysanaptic," which they meant the disproportionate growth. They reported that restriction to the alveoli and parts of the upper respiratory tracts might be caused by disproportionate growth of the airways and the lung parenchyma and that dysanaptic growth could lead to the development of different types of lung diseases. Alteration of the $FEF_{25\%}$, $FEF_{50\%}$, $FEF_{75\%}$, $FEF_{25-75\%}$, FVC, and PEFR henceforth might indicate reduced "cross-talks" between the lung parenchyma and the airways, which could lead to the development of complicated pulmonary diseases.

Our study had some limitations. First, the main restriction of this study was that there were no available data about the workplace environment and status of the air qualities in the unorganized sectors so as in the jewelery industries. It also varies from one workplace to another. In the jewelery industries, smoke and fumes generate by various means. So, it was not possible to evaluate the effect of single identity on respiratory health. Second, the study population was from the unorganized sectors where there is no proper maintenance of work schedules and assessment of hazardous substances of the workplaces.

Therefore, it is necessary to be cautious when generalizing our results. Finally, as the workers rarely work in a specific workplace for a long period, understanding the pulmonary status of the workers working at a constant location for a long time (e.g. more than 25 or 30 years) were not possible.

CONCLUSIONS

In conclusion, long exposures to workplace gases and fumes were significant risk factor for pulmonary fitness amongst the goldsmiths of Indian unorganized sectors. Our results suggested that long exposure to those pollutants abruptly altered the lung functions of the workers. Some measures that can be adopted are as follows:

1. Regular investigation of the workplaces should be performed.
2. The workers should use preventive measures such as masks as many times as possible.
3. The use of chimneys and other exhaust techniques should be provided to the workers.
4. Regular check-up of the workers should be encouraged for their health education.

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