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Original Research Article

Assessment of pulmonary function of industrial workers in four different industries of Gujarat

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ABSTRACT

Background: Industrial workers working in various industries have exposure to different kind of pollutants. Exposure to various types of dust causes pneumoconiosis, a rising cause of impairment in factory workers. This study sought to analyze the effect of quantity and quality of dust variety and the duration of exposure on the pulmonary function test of the workers.

Methods: Pulmonary function testing (PFT) was done using PC based spirometer in 4 different industries of Ahmedabad and Gandhinagar cities. The PFT values obtained were compared with normal values and the number of workers with impaired PFT was found. Associations were observed between types and amount of exposure with pulmonary impairment.

Results: Out of 909 workers, 408 (44.88%) had pulmonary impairment of which 330 (80.88%) presented with restrictive lung function. It was found that maximum restrictive lung functions were found in workers exposed to metallic dust (51.4%) followed by metallic gases (43.8%). Whereas office administrative workers not having any direct exposure were having less impairment ($p<0.005$). Also, with increased duration of work in the industry, pulmonary impairment was also increasing. ($\chi 2=119.89$; $p<0.005$).

Conclusions: Exposure to various types of dust impairs lung functions. The severity increases with the increase in the amount and duration of exposure. Proper protective measures should be taken by the workers and regular check-ups should be done to know any pulmonary impairment. The workers with impairment should be removed from exposure and relocated.

Keywords: Industrial workers, Pneumoconiosis, PFT

INTRODUCTION

The modern definition of occupational health (ILO and WHO) is: “The promotion and maintenance of highest degree of physical, mental and social well-being of workers in all occupations- total health for all at work”. It is observed that substantial economic losses are incurred by health and safety hazards at work and the reduction or loss of working capacity, as much as 10%-20% of the GNP in some countries.[1]

Leigh et al have estimated an annual incidence of occupational disease between 9,24,700 and 19,02,300, and 1,21,000 deaths in India.[2] The major occupational diseases/morbidities of concern in India are: silicosis, musculoskeletal injuries, coal worker's pneumoconiosis, chronic obstructive lung diseases, asbestosis, byssinosis, pesticide poisoning and noise induced hearing loss.

Mechanical and assembly industries have mainly copper and steel (various other metallic) dusts, silica, lead, wood, copper gases- acetylene-oxygen as the main constituents. These constituents act as pollutants and all have specific effects on the health of the workers. In the thermal power station the main pollutant is coal itself along with the high heat that is generated.

Pneumoconiosis is an occupational lung disease and a restrictive lung disease caused by exposure to various dusts. Few of them are as follow.

Coal worker's pneumoconiosis caused by long exposure to coal dust which progressively builds up in lungs; leading to inflammation, fibrosis and sometimes necrosis. It develops after the initial, milder form of the disease known as anthracosis. This is often asymptomatic and is found to some extent in all urban dwellers due to air pollution.[3] More commonly, workers exposed to coal dust develop industrial bronchitis, clinically defined as chronic bronchitis.[4]

Silicosis (grinder's disease) caused by inhalation of crystalline silica dust and is marked by inflammation and scarring in the form of nodular lesions in the upper lobes of lungs. Silicosis (particularly the acute form) is characterized by shortness of breath, cough, fever, and cyanosis (bluish skin).

Asbestosis is a chronic inflammatory and fibrotic lung disease of parenchyma which usually occurs after high intensity and/or long term exposure to asbestos.

Byssinosis is caused by exposure to cotton dust in inadequately ventilated working environments. It is believed to be caused by endotoxins released from gram negative bacteria.

Berylliosis is a chronic allergic type of lung response and chronic lung disease caused by exposure to beryllium and its compounds.

Pulmonary insufficiencies are highly prevalent in industrial workers of fabrication and assembly units in the industries due to exposure to silica dust, Fiber glass dust. Various chemicals are also known to cause many respiratory ailments.

This leads to impaired lung function and various other health hazards. Occupational exposures are a major cause of morbidity and disability. Pulmonary function tests give a clear idea about the condition of pulmonary functions and can give us the assessment of the respiratory problems suffered by the industrial workers.

The main aim of this study was to assess lung functions through pulmonary function tests (PFT) using a portable PC based spirometer.

Other objectives of this study were:

- To associate the severity of the lung diseases with the duration of exposure in the factory and with other personal habits/addiction.
- To associate the type of lung diseases with the specific unit in which they are working.

METHODS

This is a cross-sectional observational study carried out from February 2014 till October 2014. Data was collected from 909 industrial workers of four different industries. Out of these, two industries were of mechanical fabrication and assembly industries, one was thermal power station and the fourth was the office staff of the thermal power station.

Ethical clearance from the Institutional Review Board was taken. Informed written consent was taken from each subject in the study.

Out of 909 workers, 749 workers were exposed directly to various dusts and a control group of 160 (office workers who are unexposed to the industrial environment) were selected having similar age group and socioeconomic status in the industry area.

Inclusion criteria

Inclusion criteria were who had worked in the industry for a year or more; who gave written informed consent to participate in the study.

Exclusion criteria

Exclusion criteria were those having cardiovascular illness in present or past; those having kyphoscoliosis deformity; those predisposed to allergic asthma

Recording occupational and personal histories of the exposed workers

All the workers underwent a detailed socio-demographic history taking which included personal history, history of any addiction, family history and past history.

In the occupational history, department of working, working years in the specific industry and specific department and socio-economic status was collected on a pre-structured proforma.

The workers were also asked about if they had any other current or past ailments.

Pulmonary function tests

The anthropometric measurement (standing height, weight etc.) was recorded. The whole maneuver was explained to the subject and they were encouraged to practice this maneuver before doing the pulmonary function test. The spirometry functions were recorded in the sitting position using an electronic computerized portable RMS-Spirometer according to the guidelines recommended by the American Thoracic Society. [5] Each individual performed spirometry thrice to produce the best result. The room temperature was recorded between 34-36 ^{0}C during the period of study.

The spirometer measurements were performed in workers engaged in the following departments:

- Administrative Office
- Coil assembly
- Thermal power station
- Fabrication
- House keeping
- Induction Heating Hardening
- Painting
- Panel Shop
- Production
- Transformer
- Office staff of thermal power station (office staff)

In the PFT, workers had to do FVC (forced vital capacity), SVC (slow vital capacity) and MVV (minute ventilatory volume).

Out of various parameters, the following respiratory parameters were studied:

- Forced vital capacity (FVC)
- Forced expiratory volume in 1 Sec (FEV1.0)
- FEV1/FVC% ratio
- Peak expiratory flow rate (PEFR)
- FEF 25-75%

The criteria for pulmonary impairment were defined on the basis of the American thoracic society (ATS) guidelines.[5] FEV1/FVC percent values >85% predicted were considered normal and values less than <85% indicated bronchial obstruction. The pulmonary impairments were classified as per Miller's prediction quadrant.[6]

Based on the above parameters, diagnosis was done for restrictive or obstructive pulmonary disorders.

The workers were divided into the groups based on the pollutants they were exposed for further analysis of health hazards based on exposure.

Following associations were analyzed

- Association of PFT with exposure to different type of dust.
- Association of PFT with departments of the workers.
- Association of PFT with the duration of exposure.
- Association of PFT with the prevalence of smoking.

Statistical tests and software

Analysis of data was performed by using SPSS-20.0. Results of categorical responses were presented in terms of frequencies and percentages. Chi-square test was applied and p value ≤0.05 was considered significant. Moreover, Spearman and Pearson's test for correlation was also applied. Odds ratio was calculated as and when required.

RESULTS

Socio-demographic findings

A total of 909 workers from four industries were examined. Out of these, there were 881 males and 28 females.

Table 1: Age distribution of the workers.

Age groups (years)	Number of workers (%)
≤20	48 (5.2)
21-30	375 (41.25)
31-40	212 (23.32)
41-50	167 (18.37)
51-60	103 (11.33)
>60	4 (0.4)
Total workers	909

Note: Figures in parenthesis indicate percentages.

A vast majority (98.5%) were Hindus, one percent being Muslims. Most of the workers were between the age group of twenty-one to thirty and were belonging to the socio-economic classes I-III according to modified Prasad's classification.

Findings related to industrial exposures

We divided the workers into occupational categories based on their exposures. The departments of the administrative office and office staff of TPS had no or very insignificant direct exposure to any of the industrial pollutants.

Majority of the workers (78.5%) joining the industry were in the age group 16-25 years. Their duration of employment showed great variations ranging from a few months to more than thirty years. This was significant in order to relate the frequency of abnormal lung functions to the time for which the employee had been working under the hazardous conditions of the respective departments.

Table 2: Exposures in various departments.

S. no.	Departments	Exposure	No. of employees N (%)
1	Administrative department	No exposure	126 (13.86)
2	Coil assembly	Copper gases, xylene, ethyelenebenzene, cumene	50 (5.5)
3	Fabrication	Iron- oxide, copper, zinc & nickel, manganese, acetylene, O2, steel dust, lead dust, cobalt.	26 (2.86)
4	House keeping	Dust	66 (7.2)
5	Induction heating hardening	Tin, excessive heat, grease, lubricating oil	150 (16.5)
6	Painting	Xylene, benzene, silica, aluminum compounds, wood particles	67 (7.3)
7	Panel shop	Silica	42 (4.6)
8	Production	Less exposure to all the above	39 (4.2)
9	Transformer	Distillates of petroleum	38 (4.1)
10	Thermal power station	Hydro treated light naphthenic (highly refined mineral oil)	171 (18.81)
11	Office staff of TPS	No exposure	34 (3.74)

Note: Figures in parenthesis indicate percentages.

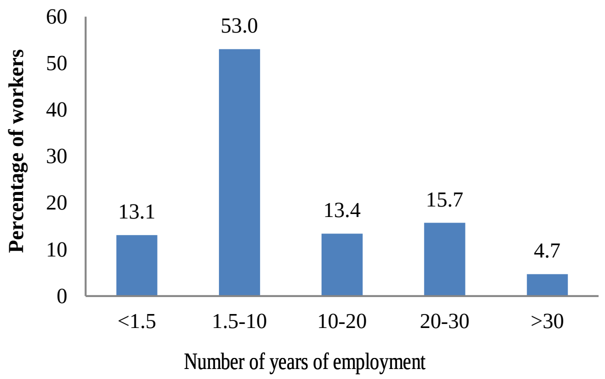

Figure 1: Duration of employment of the workers.

119 workers (13%) had worked in the industry for less than 1.5 years. Over half (53%) of the study population, had been working in the industry for more than one and a half years but less than ten years. 122 (13.4%) and 143 (15.7%) employees had been working in the industries for ten to twenty years and twenty to thirty years respectively.

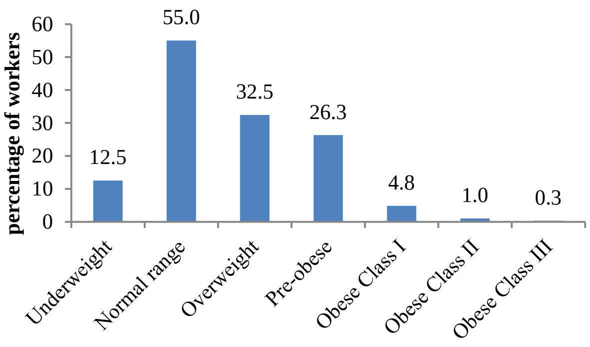

Figure 2: Body mass index of study population.

Most of the workers (55%) fell into the normal range for body mass index (BMI=18.50-24.99), but a significant number of them also fell into the overweight (BMI≥25.00) especially pre-obese (BMI=25.00-29.99) categories having around 239 (26.3%) workers. 114 (12.5%) workers were underweight (BMI<18.5).

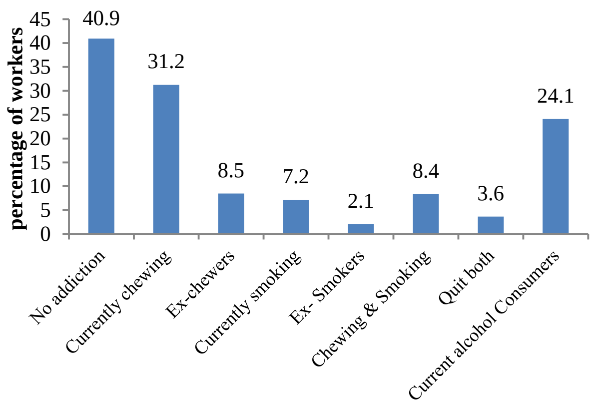

Figure 3: Number of workers versus habit.

60% of the workers assessed presented with addiction. Among them, 360 (39.6%) workers had a current habit of chewing and 110 (12.1%) workers had quit for more than six months. 141 (15.51%) workers had a smoking habit and 52 (5.7%) of the total workers had quit smoking. 219 (24.1%) workers had a habit of consumption of alcohol on a regular basis. 76 (8.4%) workers were consuming tobacco for chewing as well as for smoking.

Associated morbidities

Most of the study population (55.11% employees) had normal lung functions. Among those having abnormalities, a majority of them presented with restrictive lung function (which is the type of abnormality seen with occupational lung diseases of pneumoconiosis).

Table 3: PFT findings in the study population.

Pulmonary function tests findings	Number of workers N (%)
Normal	501 (55.11)
Mild restriction	266 (29.26)
Moderate restriction	58 (6.38)
Severe restriction	6 (0.6)
Mild obstruction	4 (0.4)
Moderate obstruction	5 (0.5)
Severe obstruction	1 (0.1)
Early small airway obstruction	26 (2.86)

266 (29.3%) employees had mild restriction, 58 (6.9%) had moderate restriction whereas only 6 (0.6%) of them presented with severe restrictive lungs. The obstructive findings, as expected were not that significant.

Table 4: Results of pulmonary function tests in different age groups.

Age (in years)	Total	Normal	Restriction	Obstruction
		N (%)	N (%)	N (%)
14-19	27	19 (70.4)	6 (22.2)	0 (0)
20-24	175	100 (57.1)	65 (37.1)	3 (1.7)
25-29	182	97 (53.3)	72 (39.6)	3 (1.6)
30-34	141	84(59.6)	51 (36.2)	0 (0)
35-39	91	47 (51.6)	32 (35.2)	3 (3.3)
40-44	78	44 (56.4)	25 (32.1)	1 (1.1)
45-49	88	49 (55.7)	30 (34.1)	0 (0)
50-54	76	37 (48.7)	30 (39.5)	0 (0)
55-59	45	20 (44.4)	18 (40)	0 (0)
60-64	4	3 (75)	1 (25)	0 (0)
>64	2	2 (100)	0 (0)	0 (0)

Note: Figures in parentheses indicate percentages; ESA= early small airway.

Associations derived: PFTs

Association between the type of exposure and findings on PFTs

The Table 5 shows that the proportion of workers with abnormal lung functions ranged between 35-45%.

The association between the type of exposure and lung functions was highly significant ($\chi2$=29.5 and p<0.0005).

It shows that the maximum restrictive lung functions were found in the study population exposed to dust including metallic dust. Coal, on the other had had a surprisingly lower value comparatively; whereas those exposed to silica having abnormal lung functions were 38% similar to the findings with lead exposure.

Table 5: Type of exposure and lung function tests.

S. No.	Type of exposure	Total no. of workers	No. of workers having PFT restriction	Percentage of exposed having PFT restriction (%)
1	Lead	26	10	38.5
2	Metallic gases	48	21	43.8
3	Dust	292	150	51.4
4	Coal	171	53	32.3
5	Silica	65	25	38.5

Association of abnormal lung functions with the departments

The Table 6 shows a variation of abnormal lung functions with the department of employment.

Table 6: Departments and lung function tests.

Departments	Abnormal PFT		Total
	No. of workers	%	
Office staff of TPS	5.00	14.71	34
Administrative office	34.00	26.98	126
Coil assembly	16.00	32.00	50
Production	22.00	33.33	66
TPS (thermal power station)	63.00	36.84	171
Panel shop	16.00	41.03	39
Induction heating hardening	28.00	41.79	67
House keeping	18.00	42.86	42
Transformer	18.00	47.37	38
Painting	13.00	50.00	26
Fabrication	126.00	50.40	250

As mentioned before, the two departments office staff of thermal power station and administrative office had no direct exposure to any of the pollutants. Nevertheless, a small percentage of the employees (14.71% and 24.98% respectively) still suffered from restrictive lung function. This can be interpreted to say that even indirect exposure, like working in the vicinity of occupational hazards can result in lung function abnormality.

Fabrication and transformer departments had the maximum amount of exposure to the various contaminants and thus majority of subjects had abnormal lung functions; 47.2% and 47.37% respectively. Fabrication-welding departments as they were exposed to maximum amount of dusts and exposures and also for longer duration in a day as compared to other departments (47.2%).

Association between duration of employment and restrictive disorders

The Figure 4 shows the association between the duration of employment of the workers in relation to the proportion of the subjects having abnormal lung function tests. On a whole, the graph shows a steady increase in the prevalence of restrictive lung functions with an increase in the duration of employment of the worker. This ranges from 37.9% of the workers having restrictive PFTs in fewer than five years of employment and around 44.7% of them presenting with restrictive lung functions when the duration of employment crosses the thirty year mark.

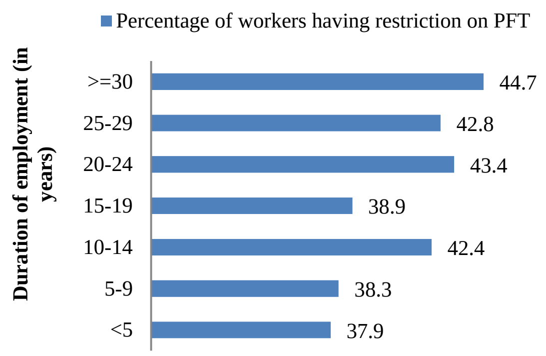

Figure 4: Duration of employment and restrictive lung functions.

These findings were statistically significant (X^2=119.89 and p<0.0001).

Table 7: Odds ratio of exposure to smoking and obstructive diseases.

Exposure	Total	Abnormal PFT (%)	Normal PFT	Odds ratio
Smokers/ ex-smokers	186	15 (8.06)	171	2.79
Non-smokers	701	22 (3.1)	723	1

These results showed that smoking was an important risk factor causing respiratory disorders. Also, it was seen that smoking mainly caused obstructive disorders.

DISCUSSION

Occupational disorders are seen in various proportions in different industrial workers working in different industries. Based on the exposure the organs affected also vary. Respiratory disorders constitute 60% of the total occupational diseases in the world and 70% morbidities are respiratory related.[7,8] This shows the prevalence of respiratory diseases and the impact of the dusts on the lungs.

In our study we have found prevalence of restrictive and obstructive disorders in workers having various different exposures and in different departments. Our results mainly pointed that, restrictive disorders were the most prevalent amongst the respiratory disorders. We found highest prevalence of restrictive disorders in metallic gases (43.8%) and fine dust (51.4%) as an exposure. Whereas based on department, fabrication (47.2%) and transformer (47.3%) departments had the highest prevalence.

There are many studies which have found the prevalence of various different types of diseases, their pathogenesis and various other factors that lead to respiratory disorders in the industrial workers.

One of the study by Nemery et al states that the type of lung disease caused by metal compounds depends on the nature of the offending agent, its physicochemical form, dose, exposure conditions and host factors.[5] Chronic obstructive pulmonary disease may result from occupational exposure to mineral dusts, including probably some metallic dusts, or from jobs involving the working of metal compounds, such as welding. Metallic dusts deposited in the lung may give rise to pulmonary fibrosis and functional impairment, depending on the fibrogenic potential of the agent and on poorly understood host factors. Inhalation of iron compounds causes siderosis, pneumoconiosis with little or no fibrosis.

The article by Antonini et al reviews shows that a large number of welders experience some type of respiratory illness. Respiratory effects seen in full-time welders have included bronchitis, siderosis, asthma, and a possible increase in the incidence of lung cancer.[9] Study by Meo, Sultan et al also shows the hazardous effects of metal and metal fumes on various organs and especially lungs that may lead to acute or chronic respiratory diseases.[10] Welding and the fabrication workers in most of the industries are exposed to maximum amount of dusts. Two different studies by Loukzadeh et al and Wolf et al found significant reduction in the pulmonary capacity of the workers doing welding work. They also found that there was significant increase in prevalence of respiratory ailments as compared to controls which showed similar results to ours.[11]

We had also seen that the administrative department employees were having less pulmonary dysfunction as compared to those who were directly exposed to different metallic and other dusts. Similar results were obtained in a study by Sharifian et al.[12] In a study by Sulotto et al 22% of workers working in such industries were having bronchial diseases. We also found similar results in our study but prevalence of respiratory disorders in the workers exposed to the above mentioned dust was 40.26% in our study.[13]

In the department of painting, carpenter and packing, the workers were exposed to wood dust, lead dust and silica dust mainly. In a study by Osman et al they also found lower PFT in the workers who were exposed to the wood dust. An increase both in FEV1 and FVC values was detected among the woodworkers who had a working period less than 10 years and were exposed to wood dust at concentrations over 4 mg/m^3 compared to the woodworkers who were exposed to wood dust at less than 4 mg/m^3. In another study by Boskabady et al similar results were found which showed significant lower PFT values in the carpenters as compared to the control group.[14,15]

In our study the PFT was decreased in the workers exposed to silica dust and prevalence of the pulmonary disorder was 33.8% as compared to the administrative workers (27%) whereas in a study by Polatli et al, they found that mean pulmonary tests were not much different in the silica exposed workers as compared to non-exposed. But they had found higher prevalence of COPD in the exposed workers.[16] In a study by Chattopadhyay et al. higher prevalence of restrictive lung disorder was seen in the workers who were exposed to the silica Dust in as compared to those not exposed.[17] This shows that silica exposure causes respiratory impairment in varying extent.

We also found that 32.3% workers in thermal power who were having mild or moderate restrictive disorder as compared to the office staff employees of the same company (14.71%). This shows that coal highly influences the lung functioning. Many studies favor that coal power plants have high impact on the workers as well as on the neighbor-hood environment. A study by Caciari et al showed similar results.[18] In a study by Goren et al, significant lower PFT findings results were obtained in those exposed to coal dust than those not exposed to it.[19] In two studies by Pala, et al and Karavus et al, it has been shown that coal burning in the thermal power plants also have deteriorating effects on the people staying in the vicinity of the plant. This shows that the coal as a pollutant effects not only the workers but also the people staying in the neighbor-hood area.[20,21]

Increased duration of work in the industry will cause more exposure to the pollutants. In our study we found that with increasing duration of exposure there was a steady increase in the prevalence of restrictive lung functions with an increase in the duration of employment of the worker. There were just 37.9% of the workers having restrictive PFTs in fewer than five years of employment and around 44.7% of them presented with restrictive lung functions when the duration of employment was greater than thirty years. The more is the exposure the more is the prevalence of the lung dysfunction and more is the severity of the disease. In a study by Chattopadhyay et al they found decrease in pulmonary functioning with increase in duration.[22] Also in another study by same author he had found decrease in the pulmonary functioning with the increase in duration.[17] Study by Wolf, et al also showed similar results to ours in which duration of work in the welding department showed a significant influence on decrease of mean expiratory flow (MEF) 25% and 50% which is similar to our results. This shows that lung capacity decreases with increased in the duration of exposure to the metallic dusts and fumes.[11]

We found in our study that odd’s of having lung diseases was 2.79 times higher in smokers as compared to non-smokers. Many studies by Boskabady et al have shown similar association between smoking and respiratory disorders. Smoking causes various harmful effects in the respiratory system especially by its constituent nicotine. In one of their study they have found that there is significant decrease in the pulmonary functioning and significant increase in the respiratory ailments in the smokers. In one of the study, pulmonary function tests (PFT) values in smokers were lower than those of non-smokers ($p<0.05$ to $p<0.001$). There were inverse correlations for PFT values and positive correlations for RS, with duration and total amount of smoking ($p<0.05$ to $p<0.001$).This showed that there was a profound effect of smoking on PFT values and respiratory symptoms.[23-25] In a study by Joseph they showed that there was a decrease in respiratory quality of life in the smokers compared to non-smokers.[26]

CONCLUSION

Occupational exposure causes restrictive as well as obstructive disorders in the workers. Regular pulmonary assessment must be carried out and if required the workers should be given pollutant free interval period in the factories. Smoking is also a contributory factor which aggravates the effect of the pollutants. Proper health awareness needs to be created about safety measures, effect of exposure and its effect and effect of smoking in all the workers.

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