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FORCED EXPIRATORY VOLUME, FORCED VITAL CAPACITY AND PEAK EXPIRATORY FLOW RATE IN WORKERS OF POWER GENERATING STATIONS

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ABSTRACT: *Air pollutants can change the compositions and functions of respiratory epithelia. This study was aimed at assessing some pulmonary functions in workers of Power Generating Stations. Four hundred and forty individuals made up of 228 workers of gas-fired power plant stations and 212 non-power generating station workers volunteered for this study. A detailed questionnaire was carefully filled by volunteers and those that met the inclusion criteria had their anthropometric data measured and recorded. Forced Expiratory Volume in one second (FEV_1), Forced Vital Capacity (FVC) and Peak Expiratory Flow Rate (PEFR) were measured. Results were presented in Mean ± Standard Error of Mean (SEM) and analysed appropriately using Microsoft excel 2010 and Statistical Package for Social Sciences (SPSS) 20. Results showed a statistically significant decrease in FEV_1 1.91 ± 0.07L, FVC which was 1.21 ± 0.02L and PEFR which was 3.42 ± 0.12L/min and of test group compared to that of the control ($P<0.05$) which was 3.45 ± 0.08L, 3.84 ± 0.05L and 5.22 ± 0.03L/min for FEV_1, FVC and PEFR respectively. In conclusion, exposure to gas emission from the natural gas-fired power plant on workers of power generating stations reduced lung function.*

KEYWORDS: forced expiratory volume, one second, forced vital capacity, peak expiratory flow rate

INTRODUCTION

Air pollution in both cities and rural areas was estimated to cause 3.7 million premature death worldwide in 2012 and 88% of those premature deaths occurred in low and middle-income countries such as Nigeria. (Mills *et al.*, 2009; WHO, 2012). The electricity industry is a major contributor to some of the most significant environmental problems facing our society playing a large role in local**,** regional, national and international environmental issues such as global warming, acid rain, ground-level ozone, air toxics, land use and water impact (the US, Environmental protection agency, 1995).

In Nigeria, about 70% of energy generation processes emit CO_2 (Sim *et al.*, 2007), though most developed nations adopt different methods to control these, like capturing methods using Denox and other counter components. However, scientist still envisaged that greater measure is required to combat the release of these harmful gases which have been linked to occupational respiratory diseases, cancer of the lungs, death to mention a few (Atash, 2007).

Occupational respiratory disease is an acute or chronic disorder that arises from the inhalation of airborne agents in the workplace and many industrial processes produce air-borne contaminants and their most common route of absorption is by the nose and airway.Air pollutants had well defined and marked systemic pulmonary inflammatory response with decreased Forced Expiratory Volume in one second (FEV_1), Forced Vital Capacity (FVC), Inspiratory and Expiratory Flow Rates (Kesavachandran *et al.*, 2006). Occupational exposure to diesel/petrol vapours has been shown to affect the effective functioning of the body systems. In automobile repair workers and petrol pump workers exposed to petrol fumes and diesel exhaust at high ambient concentrations of solvents and air pollutants, well defined and marked pulmonary inflammatory responses were also observed (Salvi *et al.*, 1999; Madhun *et al.*, 2012).

A study on pulmonary functions in petrol pump workers showed that both Peak Expiratory Flow Rate and Forced Vital Capacity were significantly reduced after exposure to exhaust fumes for a long duration (Mayanksinghal *et al.,* 2007). 25.8% of a population of automobile repair workers experienced compromised lung function out of which 21.1% had restrictive lung disease (Chahopadhyay, 2007). Chronic exposure to petrol and diesel fumes leads to chronic inflammation of respiratory tract and lung parenchyma (Salvi *et al.,* 1999).

A marked reduction in Peak Expiratory Flow Rate value was observed in subjects with prolonged exposure to gas flaring (Ovuakporaye, 2012). Inhalation of gaseous chemical and inspirable particulate matters cause inflammatory changes which lead to increased airway resistance, thereby bringing about the remodelling of the airway and consequently lung dysfunction (Iyawe and Ebomoyi, 2005). Exposure to air pollutants adversely affects lung function (Alakija *et al.,* 1990, Leonardi *et al.,* 2000; Ovuakporaye *et al.,* 2007; Ihekwaba *et al.,* 2009). Exhaled Nitric Oxide was significantly higher among exposed subjects than among controls adjusting for age and smoking (Sekkai *et al.*, 2012). Liquified Petroleum gas was reported not to have a significant effect on respiratory function.

Exposure to ozone causes a decrease in Forced Expiratory Volume in one second (FEV_1) and Forced Vital Capacity (FVC) associated with a chest discomfort on inspiration and increased non-specific air-way hyper-responsiveness (Bertein *et al.,* 2004, Olivern and Scoclotti, 2005). Air pollutants change the compositions and functions of respiratory epithelia which are associated with a variety of diseases. (Mussali- Galante and Fortuol, 2008).

Power plant workers are more vulnerable to impairment of expiratory flow (Zodpheye *et al.,* 1998). This may be due to poor ventilation, non-use of personal protective equipment and lack of proper exhaust facility (Deacon *et al.,* 1998) causing chronic bronchitis occurring due to chronic irritation of airways (Corzo and Naveda, 1998).

Combustion of fuel such as natural gas has been known to be the main cause of pollutant emission through engines (turbines for power generation) (Zuurbier *et al.,* 2011). This source of pollutant sets the lungs in a situation of constant aggression that results in a state of chronic inflammation which could lead to pulmonary fibrosis (Churg and Wright, 2002).

Aim

The study was aimed at assessing some pulmonary functions in workers of power generating stations.

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Specific Objectives

i. measure and compare Forced Expiratory Volume in one second (FEV_1), Forced Vital Capacity (FVC) and Peak Expiratory Flow Rate (PEFR) of control and test groups.

ii. determine the pattern of respiratory symptoms in the test group.

MATERIALS AND METHODS

All materials used for this study were standard and they include the following:
Weighing Scale (Avery Berkel 2003 model, UK)
Standard Stadiometer
Spirometer (Spiro Lab II, Italy)

Ethical committee approval

Ethical committee approval was obtained from the Ethical committee of the Ministry of Health, Edo State before the commencement of this work. Written, informed and Verbal consent was obtained from all volunteers.

Sample Size and Protocol

A total number of 440 volunteers made up of 228 power generating station workers (test group) and 212 non-power generating station workers (control group) including males and females participated in this study.
They were further divided into three groups based on the years spent in the company which was taken as years of exposure. This includes:

A. those that have spent 1-5 years
B. those that have spent 6-10 years
C. those that have spent more than 10 years

They were also divided into different groups based on areas of work in the company

A. those working directly in the power plants, this included the maintenance staff and operators
B. those working in the offices, this comprises of the administrative staff
C. other, this comprises of the security men, Caterers, cleaners and clinic workers.

Inclusion Criteria

Those included in this study were Age 20-60 years, had no known respiratory disease and were not on any regular medication. They had no known family history of any respiratory-related disease and had not undergone any major surgery in the past three years.

Exclusion Criteria

Those workers of gas-turbine power generating stations and control group with a history of smoking or tobacco chewers, family history of allergy were excluded from the study.

Questionnaire

A detailed questionnaire was completed by each subjects requesting information about lifetime occupational and environmental exposure to air pollution, tobacco-smoking, medical and surgical history. Standard Respiratory symptoms questionnaire was based on that described by the Medical Research Council (MRC) (1960).

MEASUREMENTS

Measurement of anthropometric parameters

Height was measured in meters using a standard stadiometer. This was done in each subject without footwear.

Weight was measured in kilograms using Avery Berked scale. Subjects were made to put off their shoes and any piece of items or objects in their possession. Thereafter subjects were made to mount the scale and their weights were read and recorded in a kilogram.

Lung Function Test

This was done with the aid of Digital Spirometer (Spirolab II, made in Italy). It was used majorly to estimate the Forced Vital Capacity (FVC), Forced Expiratory Volume in one second (FEV_1) and Peak Respiratory Flow Rate (PEFR). Test results were given as measured values in Litres using American Thoracic Society Standardisation of spirometry (1994).

Procedure for spirometry

The lung function tests were carried out using an electronic computerized portable spirometer (Spirolab II, Italy). Subjects were given proper instructions about the procedure to be performed. They took the spirometric tests in the sitting position and a nose clip was applied on the nose after which they were asked to hold the mouthpiece around the opening of the mouth in such a way that the mouth completely goes tightly around the opening of the mouth to prevent any leakage of air the entire manoeuvre. Subjects were encouraged to inspire maximally and then forcefully expire through the mouthpiece into the spirometer. Each subject had three trials and the best of the three readings was taken as the value recorded. These values were read from the spirometer screen. The parameters measured by the apparatus were the (a) Forced Expiratory Volume in the first second (FEV_1), (b) Forced Vital Capacity (FVC) and (c) Peak Expiratory Flow Rate (PEFR). For this study Respiratory impairment, obstructive, restrictive and mixed were categorized based on the following criteria. Restrictive: FVC<80% of predicted, Obstructive: FEV1% or FEV1/FVC% and PEFR <80% of predicted. Mixed: FEV1%, or PEFR < 80 % of predicted (Kesavachandran *et al.*, 2006).

Statistical Analysis

Statistical Analysis was carried out with Statistical Software Packages, Microsoft Excel, 2010 and Statistical Package for Social Sciences version 20. Results were presented as Mean ± Standard Error of Mean (SEM). For comparison of mean between the control and test groups, independent student t-test was used with a confidence interval of 95% for variables with the normal statistical distribution. Analysis of Variance (ANOVA) was used to compare means among different years of exposure and areas of work in the company. P-value < 0.05 was considered as statistically significant.

RESULTS

Measurement of Forced Expiratory Volume in one second (FEV_1)

Graphs comparing the values of FEV_1 in the control and experimental groups of both male and female subjects are shown in Figures I-II. Based on years of exposure and area of work in the company, the difference in the value of FEV_1 in the control and experimental subjects was

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different. FEV_1 Value decreased with an increase in years of exposure irrespective of the area of work in the company.

Measurement of Forced Vital Capacity (FVC)
Graphs comparing the values of FVC in the control and experimental groups of both male and female subjects are shown in Figures III-IV. Based on years of exposure and area of work in the company, the difference in the value of FVC in the control and experimental subjects was different. FVC Value decreased with an increase in years of exposure irrespective of the area of work in the company.

Measurement of Peak Expiratory Flow Rate (PEFR)
Graphs comparing the values of PEFR in the control and experimental groups of both male and female subjects are shown in Figures V-VI. Based on years of exposure and area of work in the company, the difference in the value of PEFR in the control and experimental subjects was different. PEFR Value decreased with an increase in years of exposure irrespective of the area of work in the company.

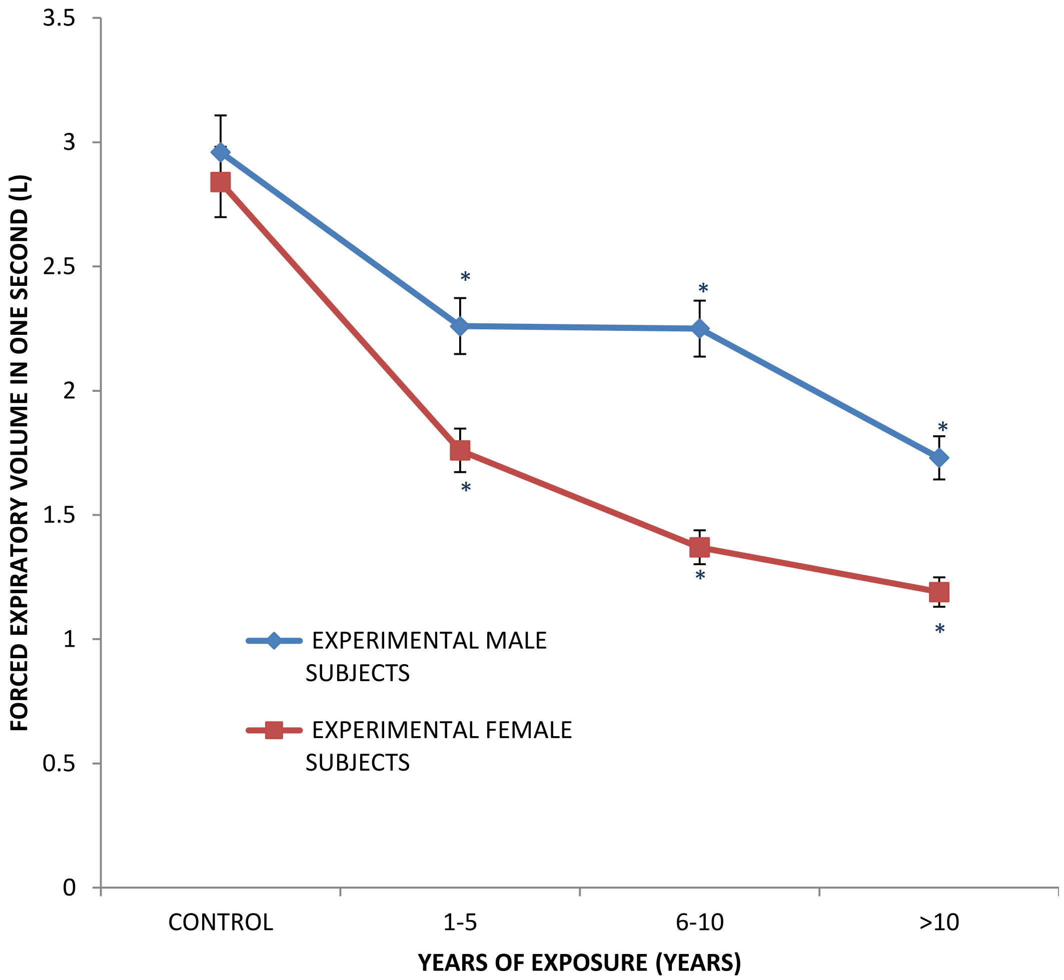

FIGURE I: showing Value of FEV_1 in the control and experimental male and female groups;

Mean ± SEM. Overall, FEV_1 for the control was higher ($P < 0.05$) than that of the experimental group in various years of the exposure group. The decrease in FEV_1 worsens with an increase in years of exposure.

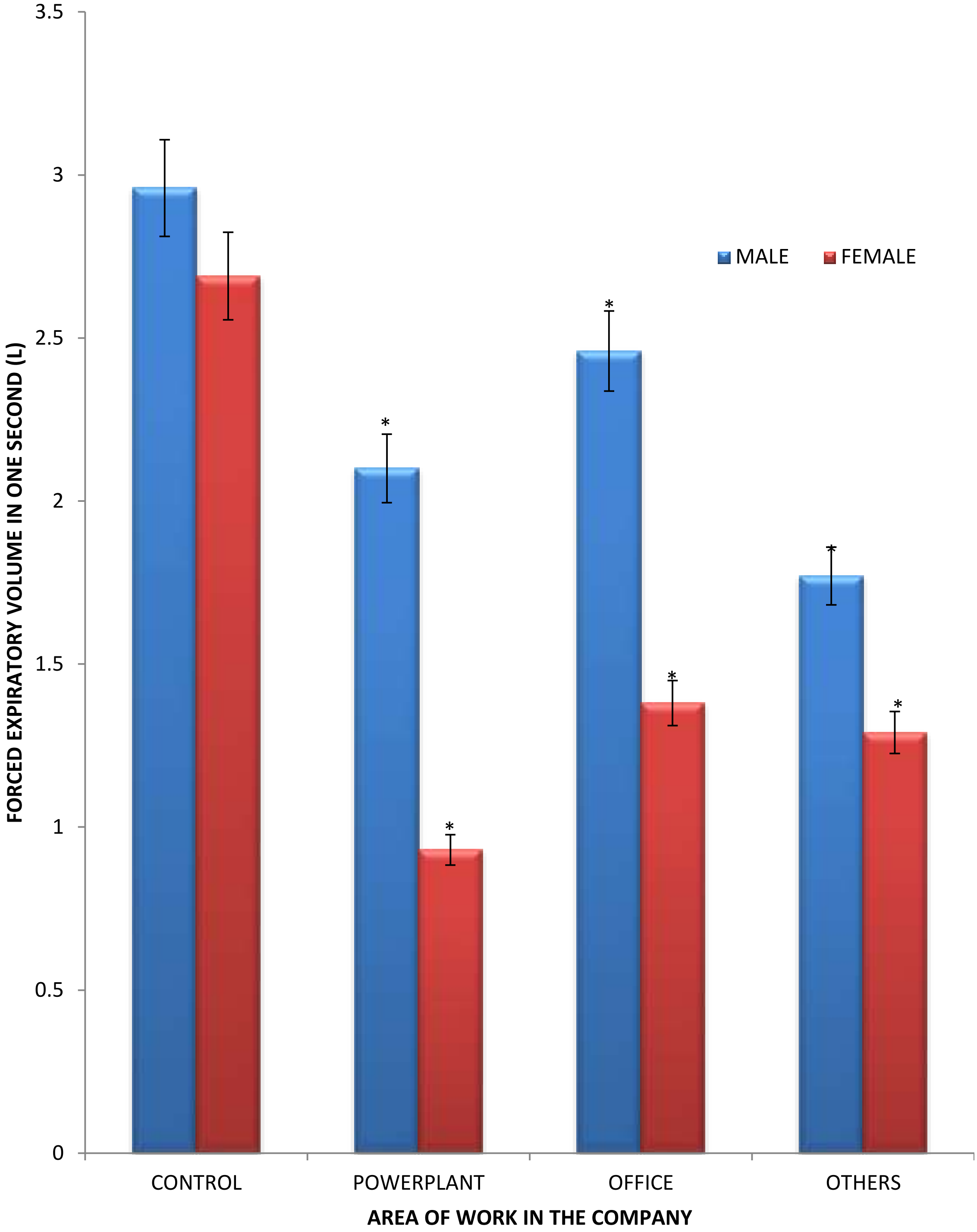

FIGURE II: showing Value of FEV_1in the control and experimental male and female groups; Mean ± SEM. Overall, FEV_1 for the control was higher ($P < 0.05$) than that of the experimental group in various areas of work in the company. The decrease in FEV_1 worsens irrespective of the area of work in the company.

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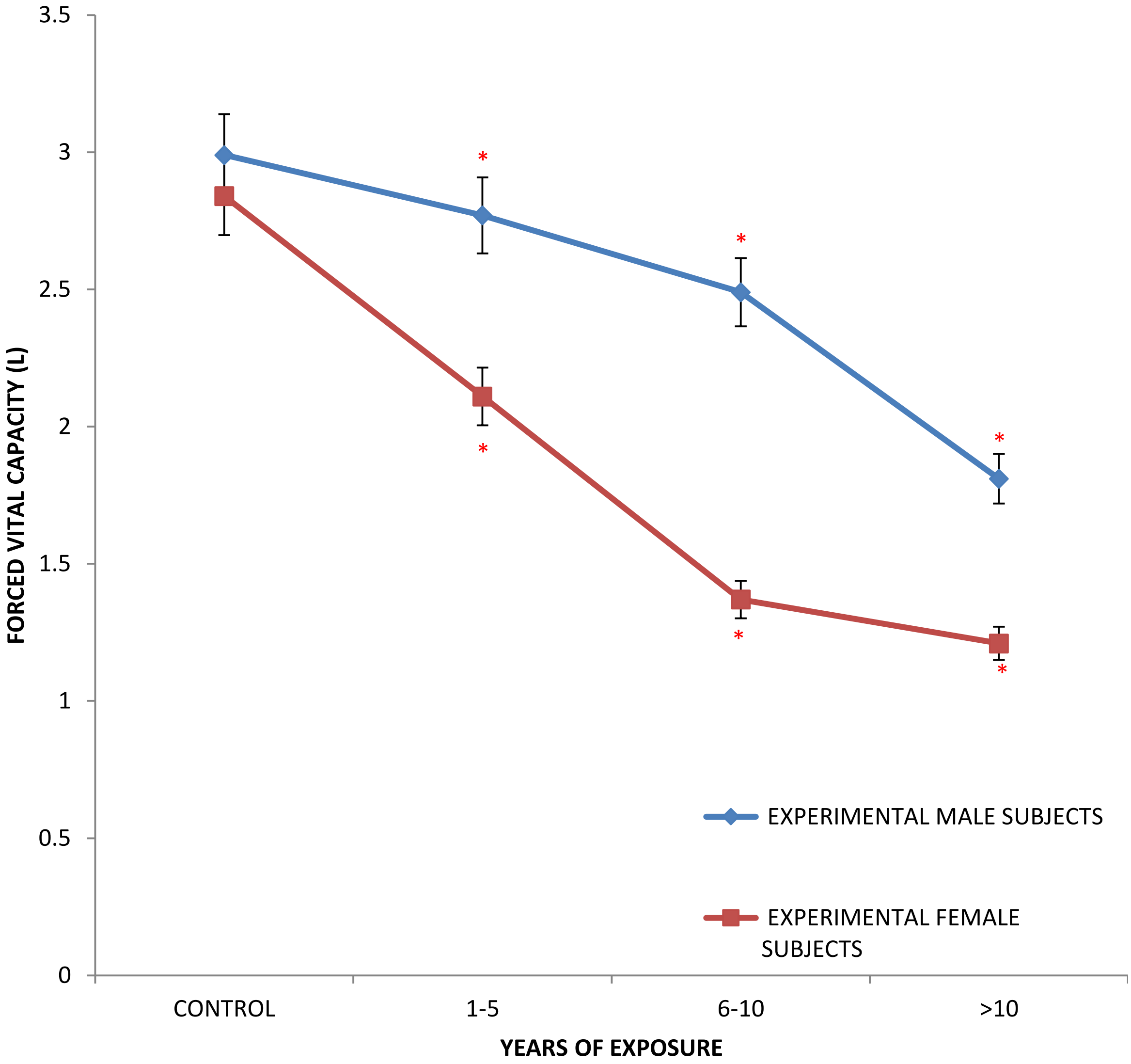

FIGURE III: showing Value of FVC in the control and experimental male and female groups; Mean ± SEM. Overall, FVC value for the control was higher ($P < 0.05$) than that of the experimental group in various years of exposure groups. FVC worsen with prolonged years of exposure.

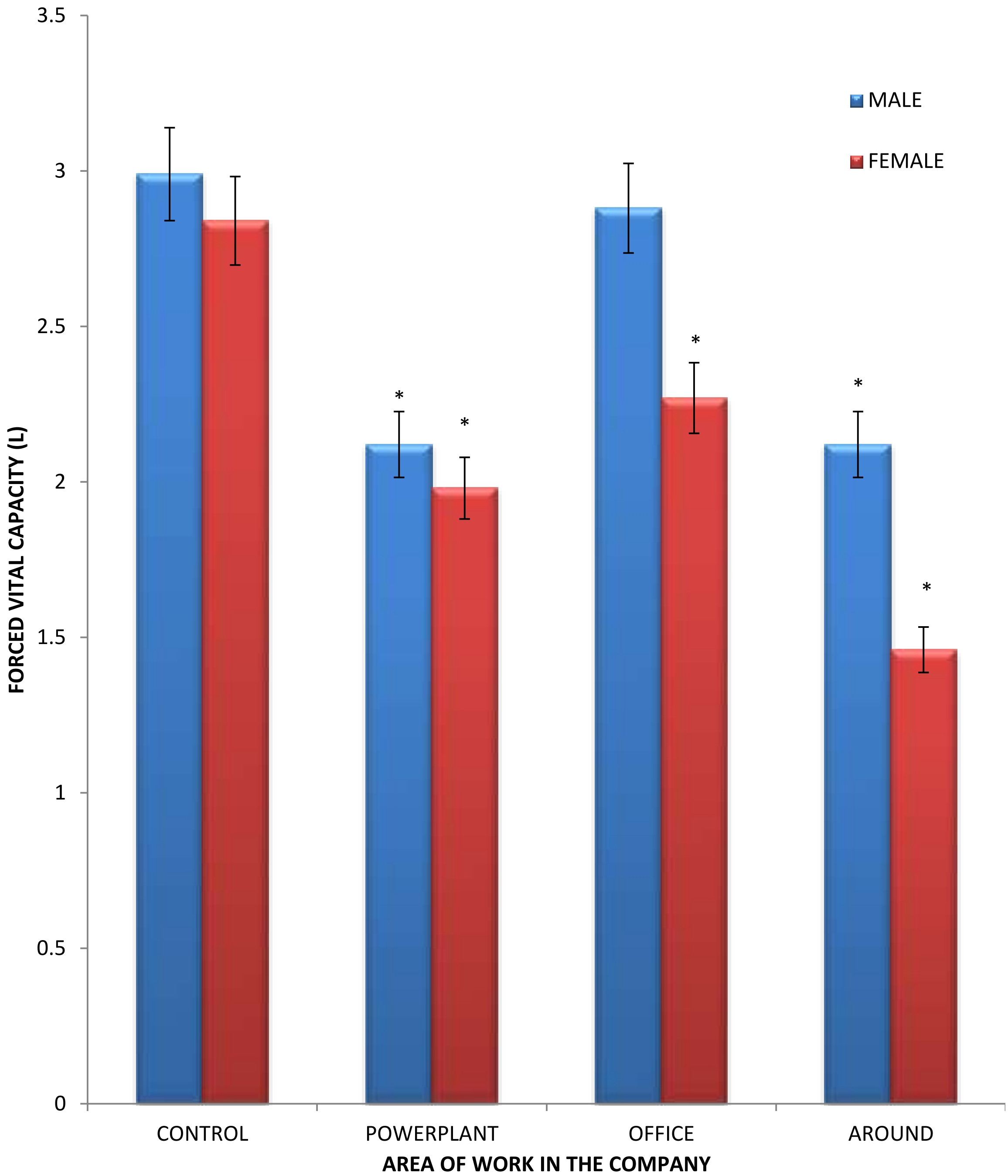

FIGURE IV: showing Value of FVC in the control and experimental male and female groups; Mean ± SEM. Overall, FVC value for the control was higher ($P < 0.05$) than that of the experimental group in various areas of work in the company. FVC decreased irrespective of the area of work in the company.

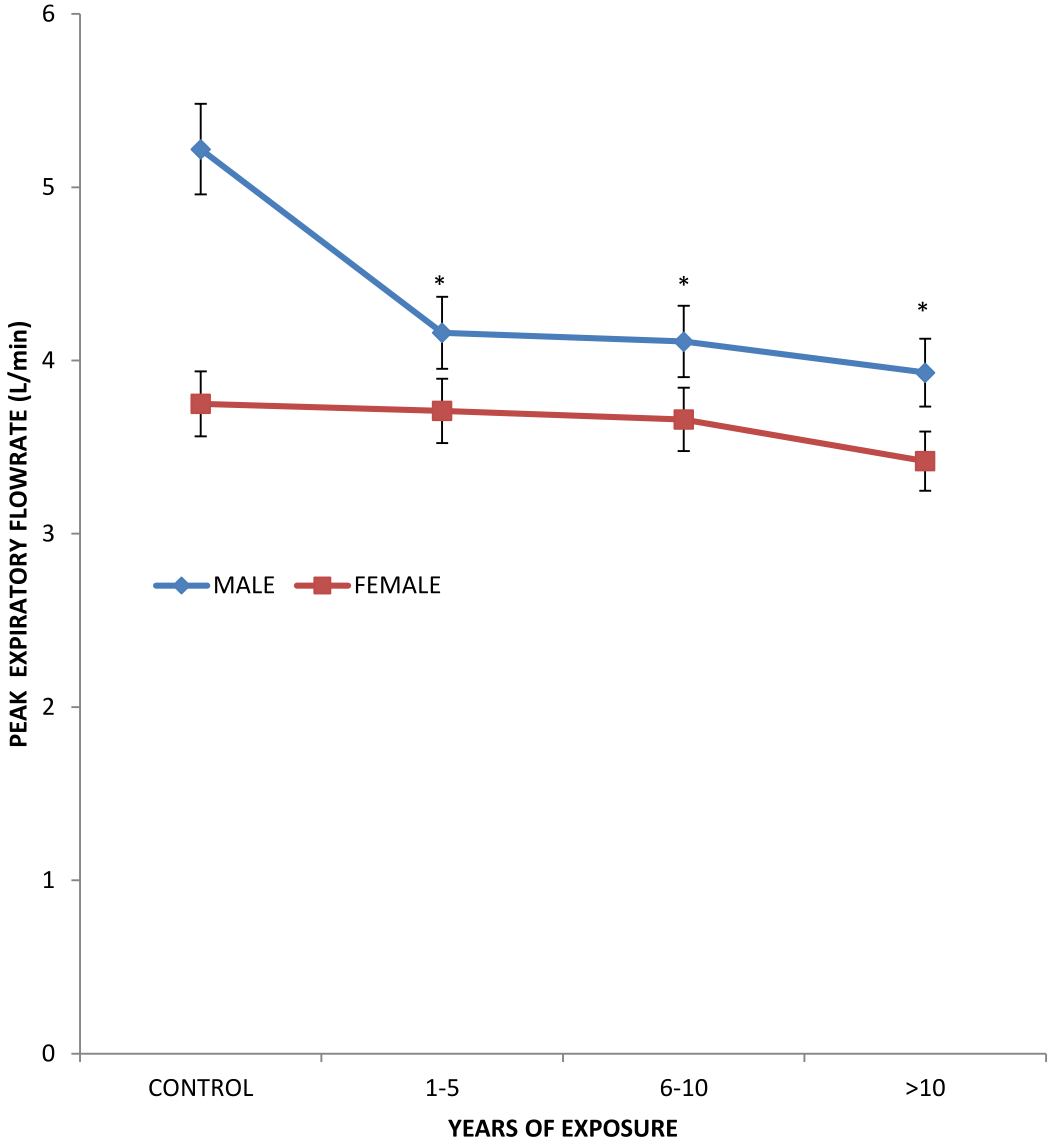

Figure V: showing Value of PEFR in the control and experimental male and female groups; Mean ± SEM. Overall, PEFR for the control was higher ($P < 0.05$) than that of the experimental group in various years of the exposure group. PEFR value worsens with an increase in years of exposure.

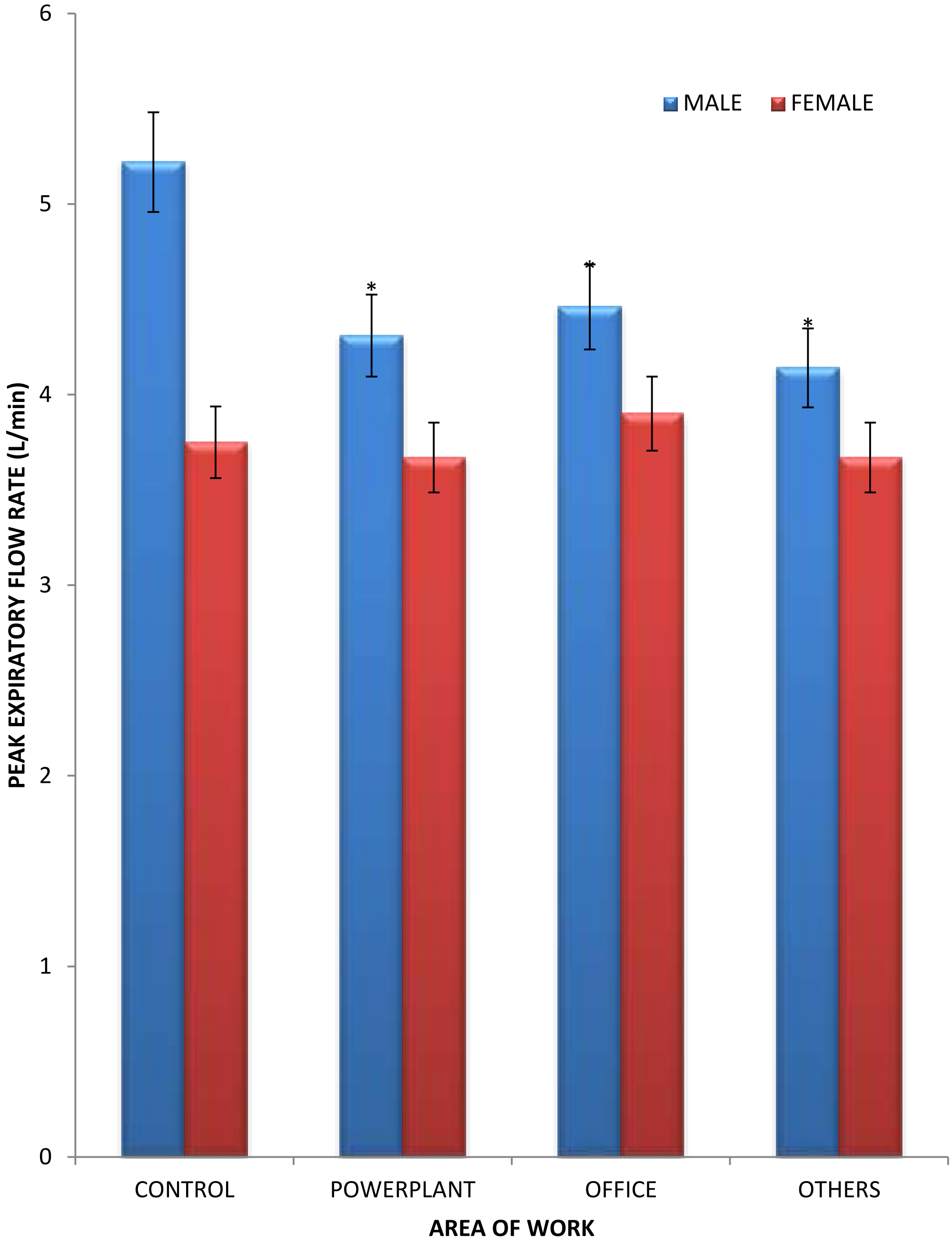

Figure VI: showing Value of PEFR in the control and experimental male and female groups; Mean ± SEM. Overall, PEFR for the control was higher (P < 0.05) than that of the experimental group in various areas of work in the company. PEFR value worsens irrespective of the area of work in the company.

Numbers of male and female subjects in the experimental group that presented with obstructive, restrictive or mixed respiratory diseases

Graph showing the numbers of male and female experimental groups that presented with the three major ventilator disorders which are obstructive, restrictive and mixed respiratory disorders are shown in Figures VII. Male experimental subjects presented with more of restrictive lung disease while the females had the same number for both restrictive and mixed pattern of lung disease.

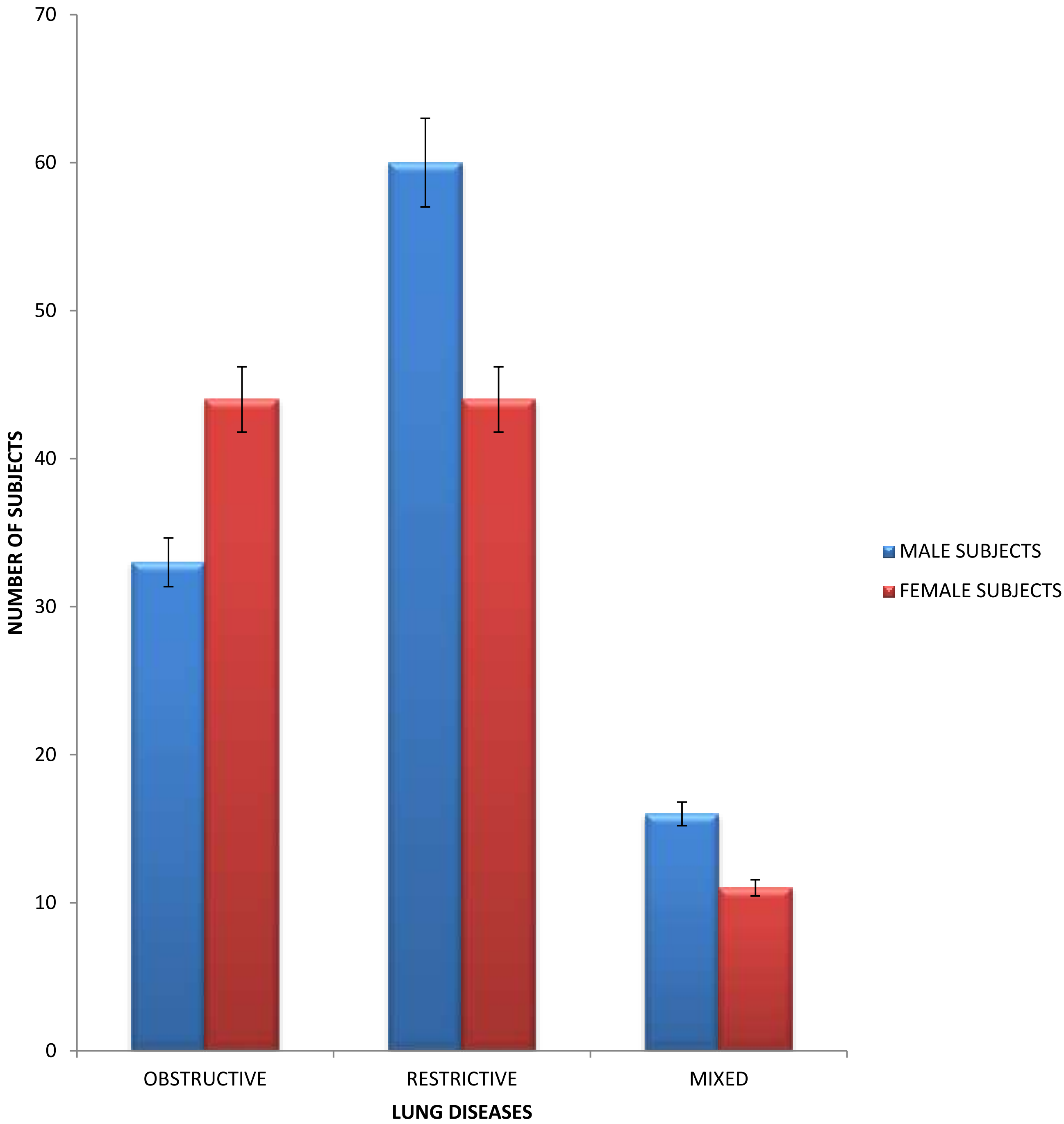

Figure VII: showing different lung diseases in the experimental group; mean ±SEM. Exposure to pollutants from power plant may result in more restrictive and obstructive lung diseases than the mixed pattern of lung disease $P<0.05$.

DISCUSSION

This study showed a decrease in FVC, FEV_1 and PEFR values in the workers in Power plants compared to values of the control. These lung function parameters decreased with the increased duration of exposure to pollutants, irrespective of the area of work in the industry in the experimental male and female groups. These are shown in Figures I-VII. The findings of the study are in agreement with reports of many researchers including the work of Singh *et al* (1988). Findings of this study are also in agreement with the work of Iyawe *et al*., (2007) and Ibhazehiebo *et al*., (2007), who observed a decrease in lung function after exposure to air pollution such as with a single puff of cigarette and flame from firewood respectively. Exposure to air pollutants like those associated with gas-fired power plants has been reported to have an adverse effect on lung functions of subjects. Reduction in lung function was observed in individuals exposed to Particulate Matter (PM) in a cement factory (Alakija *et al*., 1990).Bernstein *et al*., (2004) also reported a decrease in Forced Vital Capacity associated with chest discomfort in inspiration and increased non-specific airway hyperresponsiveness in a group of people exposed to ozone pollution.

In this study, lung function decreased with increase in years of exposure which was in line with the report of Sandstrom and colleague in 1999; they stated that both single and multiple exposures of humans to occupational concentrations of Nitrogen Dioxide resulted in the time-dependent inflammatory response in the lung. However, observations in this study did not agree with the work of Nku *et al*., (2005) who reported that there was no statistically significant difference in FVC, FEV_1 and PEFR among road sweepers and attributed it to the fact that none of them has spent more than two years in the job. This highlights the significance of the length of exposure to air pollutants and lung function impairment (Alakija *et al.,* 1990; Urom *et al.,* 2004) as observed in this study. Changes in lung function parameter in this study may be attributed to the fact that as pollutants reach the lung surfaces they cause the generation of oxidants and secondary oxidation products arising from oxidant pollutants. These initiate many cellular responses including cytokine generation, adhesion molecule expression and tight junction modification leading to the influx of inflammatory cells to lung tissue in the absence of any pathogenic challenge, lung permeability increases and oedema developed even though this process is peculiar to individuals.

The decrease in FVC may be due to many changes to the bronchi and in particular elastic component of the lungs resulting in a restrictive type of lung impairment (Mathur *et al.*, 1999). The decrease in FEV_1 shows that exposure to pollutants causes early obstructive pulmonary impairment which further increases with an increase in the number of years of exposure (Rao *et al.*, 1991). It may be due to release of airborne endotoxin which may cause an inflammatory reaction in the bronchopulmonary system also the PEFR decreases and it may be due to hypertrophy of mucosal cells due to irritation by pollutants resulting in the increased secretion of mucus and the formation of mucosal plugs, which obstruct the exhaled air (Taylard *et.al.,* 1988). The decrease in lung function parameters as reported by Iyawe and Ebomoyi, (2005) may be caused by remodelling of the airway by air pollutants. This is usually the case when pollutants affect the airway over a prolonged period as in this study.

High prevalence of respiratory symptoms such as cough was also observed in the workers in this study, which suggests that pollutants associated with gas-fired plants are allergenic (Glovsky *et al.*, 1997) and this may lead to irritation of the respiratory tract which was in agreement with research carried out in road sweeper and other dust inhaling jobs.

LIMITATIONS OF THE STUDY

i. The study did not capture power generating worker that had less than a year exposure
ii. Blood gas analysis was not carried out to ascertain the presence of pollutants in the blood.

CONCLUSION

The natural-gas-fired plant has been assumed to produce fewer emissions with no negative effect on human health. On the contrary, this study showed that exposure to emissions from gas-turbine power may have an adverse effect on the lungs, known to be more vulnerable to pollutants as shown in this study by the decrease in the lung function of workers in that environment.

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