

## Comparative study of dynamic pulmonary function tests in steel factory workers and normal individuals in Ballari

Mohammed Jaffer<sup>1</sup>, Aparna A<sup>2,\*</sup>, Tarunnum MN<sup>3</sup>

<sup>1</sup>Assistant Professor, <sup>2</sup>Associate Professor, Dept. of Physiology, GSLMC, Rajamahendravaram, <sup>3</sup>BHMS

**\*Corresponding Author:**

Email: aparna.reddy28@gmail.com

### Abstract

**Introduction:** Ballari is one of the hot spots in mining activity. The Steel plant in the planning Area is favorably situated in regard to the availability of raw-materials required for the development of industries. Nearly around 60 steel and sponge heavy industries are present in and around Ballari.<sup>(1)</sup> Till now there are very few studies done in India on these populations regarding their respiratory health. So this study may give some insights of the occupational respiratory diseases in steel workers of Ballari.

**Objective:** To assess the effect of dust exposure on dynamic PFT of steel workers and compare with that of healthy age matched controls

**Materials and Method:** Study conducted on 50 male steel workers of age 20-40 years exposed to dust & on age matched controls (50) at VIMS, Ballari. Ethical clearance was taken from the institution before conducting this study. Statistical software: SPSS 21 used. Dynamic PFT's: FVC, FEV1, FEV1/FVC, FEF 25-75 % and PEFR were measured by using RMS Helios 401 spirometer.

**Results:** There was a statistically significant decrease in the level of FVC, FEV1, FEV1/FVC %, FEF<sub>25-75%</sub> and PEFR in cases compared to the controls. Among cases 30% of them were suffering from early small airway obstruction & mixed blockage, 76% of them were suffering from restrictive type of COPD severity.

**Conclusion:** The lowering of all the dynamic PFT's compared to controls suggested a combination of restrictive & obstructive patterns in their lungs. Reduction in their dynamic lung functions was possibly associated with exposure to dust. Evaluation of the dynamic PFT with paucity of related symptoms of early lung dysfunction constitutes an important feasible and reproducible screening technique. It should be included as a routine in the periodic assessment of steel factory workers as it often uncovers early lung dysfunction even in the asymptomatic state.

**Keywords:** Spirometry, steel workers, FVC: Forced Vital Capacity, FEV1: Forced Expiratory Volume in 1sec.

**Received:** 18<sup>th</sup> July, 2017

**Accepted:** 14<sup>th</sup> September, 2017

### Introduction

Ballari is being identified as one of the hot spots in mining activity. About 95% of the industries located in the region are causing air pollution. Polluting industries in Ballari are Steel Industries, Iron ore processing industries, Stone crusher, Jean Washing units & Cotton ginning industries.<sup>(1)</sup> The region is fortunate to have the deposits of minerals such as copper, iron, manganese, galena, gypsum, magnetite quartz, soap stone & decorate building stones. The chief among all these are the iron & manganese ores.<sup>(1)</sup> The Steel plant in the planning Area is favourably situated in regard to the availability of raw-materials required for the development of industries. Nearly around 60 steel and sponge heavy industries are present in and around Ballari.<sup>(1)</sup> As the 21<sup>st</sup> century begins, steel is stronger and more durable than earlier steel. Steel is the most recycled material by weight. Iron is the world's most commonly used metal and can usually be found with other elements in the form of steel.<sup>(2)</sup> In India there are approximately 60 million workers over the age of 16, involved in various kind of industrial work, such as steel and textile industry which leads to different types of pollutions. The workplace is that in which a person not only earn his daily bread but also spent 1/3<sup>rd</sup> of his

average adult life. Thus the workplace has significant influence on individual's health and it is a primary site for the delivery of preventive health care.<sup>(3)</sup>

Steel workers are potentially exposed to a variety of pollutants originating from iron ore, coal, silica, fumes and gases that comprise furnace emissions, metal fumes, iron oxides, and oxides of carbon, sulphur, and nitrogen which may adversely affect their respiratory health. Several studies reported that unprotected dust exposures in steel production may lead to impairment of lung function.<sup>(4,5,6)</sup> These workers, therefore, are at an increased risk of impaired lung function from chronic exposure to dust and fumes. The frequently recorded health disorders between iron and steel industry workers includes: Respiratory (66%), Skin problems (31%) and noise related hearing impairment.<sup>(7)</sup> Occupational exposures to dust, fumes, and gases are associated with increased prevalence of respiratory symptoms and impairment of lung function.<sup>(8)</sup> Chronic obstructive airway diseases have been well documented as being result of such exposure. However, few studies have been reported on the effect of metal dust exposure. Metal dust is known to have high metallic content.<sup>(9)</sup> This metallic dust may cause pulmonary diseases namely pneumoconiosis,

bronchitis, and possible lung cancer.<sup>(10,11)</sup> Almost all occupational diseases are known to cause permanent disablement and there is no effective treatment. However most occupational diseases can be prevented by adopting proper occupational health measures and control of hazards at work place.

In occupational respiratory diseases, Spirometry is one of the most important diagnostic tools. It plays a significant role. It plays an important role in the diagnosis and prognosis of these diseases and describes effect of restriction or obstruction on the lung function.<sup>(12)</sup> Periodic testing in workers can detect pulmonary disease in its earlier stages when corrective measures are more likely to be beneficial. In view of the fact that various airborne particulate, dust puts the workers health into jeopardy and most of the workers in India do not use protective measures and very few studies in these steel workers have been reported in North India, so this study was undertaken to assess the effect of dust exposure on dynamic PFT of steel workers and compare with that of age matched healthy individuals in Ballari, South India.

### Materials and Method

This comparative study was carried out in the Medical check-up room of Mahamanav Ispat Steel Ltd, Belagal Village, Ballari and in the Research laboratory, Department of Physiology, Vijayanagar Institute of Medical Sciences, Ballari during September 2013 to March 2014. The sample population for the above study was selected from both the rural and urban population of Ballari. Total sample size 100. Two study groups were selected from the above sample population. Informed written consent and a clinical history were taken, using a structured questionnaire to conduct the various examinations. Each group had a sample size of fifty subjects who were selected using simple random sampling. Group 1 is the case group consisting of fifty male steel workers who were exposed to dust during working hours in steel factory in the age groups between 20-40 years with minimal respiratory symptoms of occupational lung disease.<sup>(13)</sup> The work is of three 8-hour shifts/day for seven days/week. The melt shop and rolling mill lines workers are those who are exposed, strongly, to hazards of noise, vapour, dust and fumes. Persons with history of respiratory diseases, cardiac diseases, neurological diseases, severely obese individuals, Individuals with significant spinal and skeletal deformities, habits of smoking and alcohol intake were excluded from the study. Satisfying the exclusion criteria's out of 200 steel workers in this factory we got only 50 male steel workers fit for our study. Group 2 is the control group. For this group fifty healthy male volunteers were selected from the study population other than steel workers, who were working in VIMS campus, Ballari, as security guards.

Examination proforma by Questionnaire method used for recording history and clinical examination

findings was designed and validated to collect data on smoking habits, socioeconomic status, past history of pulmonary diseases, current respiratory symptoms (chronic cough, chronic phlegm, wheezing and whispering, breathlessness, dyspnea in efforts), education, job exposure matrix, and other parameters.<sup>(14)</sup> Portable weighing machine, measuring tape, Stethoscope and Mercury sphygmomanometer were used to record physiological parameters. Portable computerized spirometer of RMS company, Model-Helios-401, attached to the laptop for recording the dynamic PFT was used. Glutaraldehyde solution 5% (Korsorex Rapid) for sterilizing the turbine transducer of Helios 401 and mouth pieces to avoid cross contamination was used. Ethical clearance was taken from the VIMS, Institution before conducting this study.

The tests were carried out on the two groups in a relaxed state and privacy was given utmost importance.

1. **Record of physical anthropometry of subjects:** Height (in cms) of the subjects was measured in standing and erect posture. Weight (in Kgs) was recorded using standard weighing machine both for study and control group in standing posture. BMI was calculated using the Quetelet index, is a measure of relative weight based on an individual's mass and height. IOTF-proposed classification of BMI categories for Asia was applied to the cases.<sup>(16)</sup> BSA was calculated using the Dubois and Dubois formula.
2. **Record of physiological parameters of subjects:** Pulse rate, Respiratory rate & Blood pressure was measured by mercury sphygmomanometer in mm of Hg.
3. In recording the dynamic PFT using Helios-401 spirometry, subjects were trained in test performance. Before examination each subject was given the opportunity to learn the technique while watching others blew into the spirometer. During the test the subject was adequately encouraged to perform his optimum level. Nose clip was used to allow air to flow only through the patient's mouth. The subjects sat upright holding the hand piece to their mouth and throughout the manoeuvre they tried to keep their back straight as much as possible. Alternatively, the transducer kept in place until the device detected the end of the expiratory manoeuvre according to American Thoracic Standard (ATS) criteria. This criteria was satisfied when the volume accumulated during the last second lower than 0.03 liters.

Each subject produced at least three acceptable FVC curves based on ATS standards. Each spirometric test was repeated 3 times to allow the choice of the best values according to the criteria. (2 values of FEV1 and FVC should not differ by more than 5% or 100ml). The equipment used for pulmonary function measurements was calibrated using a 3 L syringe, before and after

each day's use without any significant differences being found.<sup>(17)</sup> As the spirometer was a flow-measuring device, it was reasonable to neglect the body temperature pressure saturated (BTPS, temperature-37<sup>0</sup> C, ambient pressure, saturated with water vapour at 37<sup>0</sup> C) conversion under environmental conditions. The transducer and mouthpiece were completely immersed into the Glutaraldehyde solution 5% for 20 minutes to disinfect and for 10 hours to sterilize at 25<sup>0</sup>.

Based upon the subject's age, gender, height and weight data, and the Spirometry equation selected, numerical values of the parameters were predicted. The spirometer equation selected for this study was according to ERS 93 (European respiratory society). The actual values obtained during a manoeuvre were listed under % PRED (Predicted) as a percentage of the predicted values. An interpretative result of the FVC

manoeuvre was given by plotting the results. Interpretation was only performed for the FVC test. Depending on where the values of FVC% PRED and (FEV1/FVC)% PRED lie, the patient's lung condition was suggested to be: Normal (NORM), Restrictive (RES), Mixed (MIXED) & Obstructive (OBS).

Statistical software namely SPSS 21 version was used for the analysis of the data and Microsoft Word 7 and Microsoft Excel 7 have been used to create text documents, graphs, tables etc.

## Results

The results obtained were expressed as Mean  $\pm$  SD, Statistical technique like independent t-test & P value were used for analyzing data.

**Table 1: Anthropometric parameters of study subjects**

| Vital parameters         | Groups                   |                             | P value    |
|--------------------------|--------------------------|-----------------------------|------------|
|                          | Cases<br>(Mean $\pm$ SD) | Controls<br>(Mean $\pm$ SD) |            |
| Respiratory rate (n/min) | 18.92 $\pm$ 2.9          | 14.80 $\pm$ 1.3             | <0.05 (S)  |
| Pulse rate (beats/min)   | 84.84 $\pm$ 6.5          | 78.44 $\pm$ 5.9             | <0.05 (S)  |
| SBP (mmHg)               | 114.08 $\pm$ 8.3         | 116.12 $\pm$ 5.8            | > 0.05(NS) |
| DBP (mmHg)               | 77.56 $\pm$ 6.8          | 75.60 $\pm$ 5.1             | > 0.05(NS) |

HS- Highly significant, S- Significant, NS- Not significant

**Table 2: Comparison of vital parameters**

| Anthropometry     | Groups                   |                             | P value     |
|-------------------|--------------------------|-----------------------------|-------------|
|                   | Cases<br>(Mean $\pm$ SD) | Controls<br>(Mean $\pm$ SD) |             |
| Height (cms)      | 165.7 $\pm$ 7.8          | 167.5 $\pm$ 4.7             | > 0.05(NS)  |
| Weight (Kgs)      | 58.7 $\pm$ 11.7          | 62.4 $\pm$ 9.7              | > 0.05 (NS) |
| Body Mass Index   | 21.31 $\pm$ 3.5          | 22.46 $\pm$ 3.1             | > 0.05(NS)  |
| Body surface Area | 1.64 $\pm$ 0.17          | 1.66 $\pm$ 0.11             | >0.05 (NS)  |

HS- Highly significant, S- Significant, NS- Not significant

**Table 3: Comparison of Lung volumes**

| Dynamic PFT'S | Groups                   |                             | P value    |
|---------------|--------------------------|-----------------------------|------------|
|               | Cases<br>(Mean $\pm$ SD) | Controls<br>(Mean $\pm$ SD) |            |
| FVC           | 72.64 $\pm$ 12.7         | 94.08 $\pm$ 6.7             | <0.05 (S)  |
| FEV1          | 69.74 $\pm$ 11.6         | 96.58 $\pm$ 8.7             | <0.05 (S)  |
| FEV1/FVC      | 96.96 $\pm$ 12.5         | 102.24 $\pm$ 3.9            | 0.005 (HS) |
| FEF           | 63.76 $\pm$ 2.9          | 89.12 $\pm$ 1.2             | 0.001 (HS) |
| PEFR          | 60.28 $\pm$ 1.8          | 81.92 $\pm$ 1.8             | 0.001 (HS) |

HS- Highly significant, S- Significant, NS- Not significant

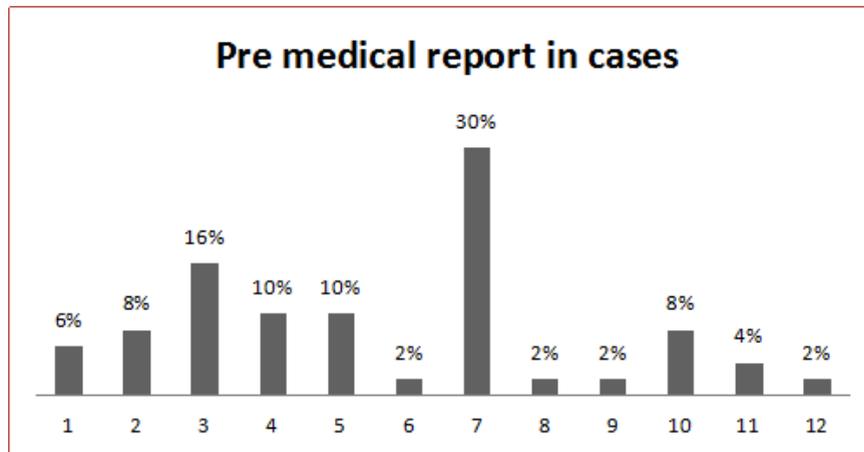


Fig. 1: Pre medical report in cases

1. Normal (N) 7. ESAO & mixed blockage (MB)
2. Early small airway obstruction (ESAO) & N 8. ESAO & severe restriction (SR)
3. ESAO & mild restriction (mR) 9. ESAO & severe obstruction (SO)
4. ESAO & moderate restriction (MR) 10. mild restriction (mR)
5. ESAO & mild obstruction (mO) 11. moderate restriction (MR)
6. ESAO & moderate obstruction (MO) 12. mild obstruction (mO)

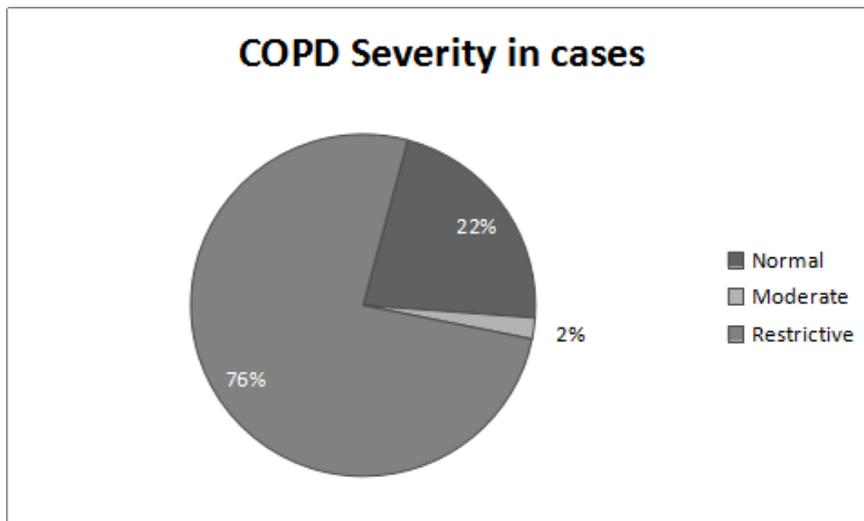


Fig. 2: Pre-test COPD severity in cases

This categorization of the pre medical report & pre test COPD severity was based on the European respiratory society 97 build up in the Helios 401 computerized spirometer.

1. N- FEV1/FVC % PRED > 95 & FVC% PRED >80.
2. ESAO - FEF 25-75 % PRED or PEFr % PRED <70
3. mO- FEV1/FVC % PRED <95 and FVC% PRED >80
4. MO- FEV1/FVC%<84 and FVC%>80
5. SO- FEV1/FVC%<65 and FVC%>80
6. MB- FEV1/FVC % PRED < 95 and FVC% PRED <80.

7. mR- FEV1/FVC % PRED > 95 & FVC% PRED <80
8. MR- FEV1/FVC % PRED > 95 and FVC% PRED <64
9. SR-FEV1/FVC %>95 and FVC % <44

**Pre Test COPD Severity**

1. N- With in normal limits
2. M- Moderate stage COPD as FEV1/FVC % <70% & FEV1 between 50 to 80%
3. R- Restrictive stage COPD as FEV1/FVC % >= 70% & FEV1<80%

## Discussion

In this study, age, height, weight, BMI & BSA were significantly matched between cases and controls (Table 1). Mean pulse rate and respiratory rate were high in the cases compared to the controls (Table 2). High pulse and respiratory rate seen in the asymptomatic cases compared to controls indicating early lung dysfunction. With restrictive lung dysfunction the work of breathing was increased to overcome the decrease of the lung compliance.

There was a statistically significant decrease in the level of FVC and FEV1 and statistically highly significant decrease in the levels of FEV1/FVC %, FEV 25-75% and PEFR in cases compared to controls (Table 3). All the dynamic PFT decreased values in cases representing mixed type of lung disorders. Similar findings were also reported in their study by Rasoul GMA et al<sup>(18)</sup> (2009), Bala S & Tabaku A<sup>(19)</sup> (2010), Singh LP et al<sup>(20)</sup> (2013), and Nurul, A.H et al<sup>(21)</sup> (2014). Among cases 30% of them were suffering from early small airway obstruction & mixed blockage, 76% of them were suffering from restrictive type of COPD severity (Fig. 2 & 3). Similar findings were also reported in their study by Edani NA et al<sup>(22)</sup> (2008). According to these studies, the inhalation of metallic dust particles containing mineral ores mainly iron is causing the oxidative damage to the lungs and leading to the mixed type of lung disorders.

Till now there are few comparative studies done in North India, comparing dynamic PFT's among steel workers men & normal individuals. In this study we have proved that steel factory male workers show a mixed (restrictive & obstructive) pattern of dynamic PFT's compared to controls in Ballari, South India. Dust, fumes, and increased hot environment exposure particularly the workers involved in casting section might have caused mixed pattern of lung disorders which may be attributed to occupational asthma.

Particles ~2.5–10 $\mu$ m (coarse- mode fraction) contain crystal elements such as silica, aluminium, and iron. These particles mostly deposit relatively high in the tracheobronchial tree. Minute particles are formed when molten metals coagulate in air due to temperature gradients outside the furnace. Without proper personal protective equipment (not readily available in developing countries) these particles are easily inhaled, reach the alveoli, and have permanent damaging effects on respiratory function.<sup>(22)</sup> Fine particles (<2.5 $\mu$ m) are created primarily by the burning of fossil fuels or high-temperature industrial processes resulting in condensation products from gases, fumes, or vapours which are prevalent in Steel factories.<sup>(23)</sup>

Inorganic compounds rich in iron, nickel, and chromium, are well known in modifying the biological effects of dust exposure. Oxidant induced cytotoxicity may play a role in pathogenesis of pulmonary disorders associated with iron.<sup>(24,25)</sup> COPD is a leading cause of mortality and morbidity in both developed and

developing countries and its natural history is mainly characterized by progressive irreversible decline in lung function as measured, for example, by the FEV1.<sup>(26)</sup>

## Limitations

The present study would have been better with a larger sample size. Assessment of respirable particulate matter in and around the working place of workers that affected the lung functions were not measured because of non-availability. Diffusing capacity of lung studies would have made the study better. Other investigations which would have made definite diagnosis of the affected workers like chest radiograph were not done. Heat stress in steel workers was not assessed which might alter the lung functions. Other investigations which would have made definite diagnosis of the affected workers like Blood investigations for WBC, DLC, ESR, CRP, Skin allergy tests & chest radiograph were not done. Hence further studies should be done on these steel workers to elaborate on the cause of the mixed type of lung disorders.

## Conclusion

Evaluation of the dynamic PFT by computerised spirometer in male steel workers of Ballari with paucity of related symptoms of early lung dysfunction constitutes an important feasible and reproducible screening technique. It should be included as a routine in the periodic assessment of steel factory workers as it often uncovers early lung dysfunction even in the asymptomatic state. It is also a pointer to embark upon a search for other complications of occupational lung diseases in steel factories like Lung cancer. The lowering of all the dynamic PFT compared to controls suggested a combination of obstructive and restrictive patterns in their lungs. Computerised Spirometer remains a cost effective, a simple non –invasive diagnostic tool and its judicious use can give warning signal for cases to take early preventive measures. Even though the factory is providing the protective measures against dust exposure like Masks, Caps, Eye goggles, the workers were not wearing it while working which may be the case for this mixed type of lung disorders. Thus periodic lung function tests for every 3 months should be done on this population along with health education and its implementation should be regularly monitored.

## References

1. Master Plan (Revision-I)-2021 (Provisional) Bellary-Sandur Local Planning Area. Sec.4 (a) (3) of KTCP act 1961 Government of Karnataka; 1993 July.7-42 p.Vide notification No: VaNaEe/164/TTP/93.
2. Chatterjee and Amit: "Recent developments in iron making and Steelmaking." J. of the Iron and Steel Inst.1995;188:100-4.
3. Susan L Janson, Julie Roberts. Asthma management across the life span: application for the adult and older

- adult. *The Nursing Clinics of North America* 2003;38:675-687.
4. El-Zein M, Infante-Rivard C, Malo JL, Gautrin D. Is the metal fume fever a determinant of welding related respiratory symptoms and/or increase bronchia responsiveness? A longitudinal study. *Occupational Environmental Medicine* .2004; 62:688-94.
  5. Becklace MR, Occupational exposure: Evidence for a causal association with chronic obstructive pulmonary diseases. *American Review of Respiratory Diseases* 1989;140 (Supp 1):S85-91.
  6. Rodriguez V, Tardon A, Kogeninas M, Preito CS, Cueto A, Garcia M, Memedez IA, Zaplana J. Lung cancer risks in iron and steel foundry workers: A nested case control study in Austria, Spain. *American Journal of Industrial Medicine* 2000; 38:64450.
  7. Chandran Achutan D and Jeffrey Nemhauser MD. Health hazard evaluation report COL-FIN specialty steel Fallston, Pennsylvania. 2007: 3-9. Report no:2003-0175-3033.
  8. Lebowitz MD. Epidemiological recognition of occupational pulmonary diseases. *Clin Chest Med* 1981, 2:305-316.
  9. Ladou J. *Occupational and Environmental Medicine*. 3rd edition. New York: McGraw-Hill;1997.
  10. Xu Z, Brown LM, Pan G-W, et al. Cancer risks among iron and steel workers in Anshan, China, Part II: Case-control studies of lung and stomach cancer. *American Journal of Industrial Medicine* 1996;30: 7-15.
  11. Bradshaw LM, Fishwick D, Slater T, et al. Chronic bronchitis, work related respiratory symptoms and pulmonary function in welders in New Zealand. *Occupational Environmental Medicine* 1998;55:150-4.
  12. Wagner NL, Beckett WS, Steinberg R. Using spirometry results in occupational medicine and research. Common errors and good practice in statistical analysis and reporting. *Indian J Occup Environ Med*. 2006;10(1):5-10.
  13. Balmes J, Becklake M, Blanc P, et al. Environmental and Occupational Health Assembly, American Thoracic Society. American Thoracic Society Statement: occupational contribution to the burden of airway disease. *Am J Respir Crit Care Med*. 2003;167(5):787-97.
  14. Chang CC. Study on the pneumoconiosis of foundry workers in central Taiwan [masters thesis]. Taichung: Institute of Environmental Health, China Medical College; 1995.
  15. Spirometer Helios 401, User Manual Version 1.0.0, Recorders & Medicare Systems, Chandigarh. India. Available from [www.rmsindia.com](http://www.rmsindia.com).
  16. Weisell RC. Body mass index as an indicator of obesity. *Asia Pacific J Clin Nutr*.2002;11: S681-S684.
  17. Standardization of spirometry, 1994 update. American Thoracic Society. *Am J Respir Crit Care Med*. 1995 Sep;152(3):1107-36.
  18. Rasoul GMA, Mahrous OAE, Mahmoud E, et al. "Auditory and Respiratory health Disorders among Workers in an iron and Steel Factory." *Zagazig Journal of Occupational Health and Safety* 2009;2(1):1-10.
  19. Bala S, Tabaku A: "Chronic Obstructive Pulmonary Disease in Iron-Steel and Ferrochrome Industry workers". *Cent Eur J public Health*. 2010;18(2):93-98.
  20. Singh LP, Bhardwaj A, Deepak KK. Occupational Exposure to Respirable Suspended Particulate Matter and Lung Functions Deterioration of Steel Workers: An Exploratory Study in India. Hindawi Publishing Corporation. *ISRN Public Health*. Volume 2013 (2013), Article ID 325410, 8 pages. Downloaded at <http://dx.doi.org/10.1155/2013/325410>.
  21. Nurul AH, Bahri SMT, Noor HI. Respiratory symptoms and pulmonary function among male steel workers in Terengganu, Malaysia. *Malaysian Journal of Public Health Medicine* 2014;Vol. 14(1):10-18.
  22. Edani NA, Khalid LO, Delaime AR. The use of pulmonary function test to predict occupational lung disease among workers in Basarah steel industry. *MJBU*. 2008;26(2):94-96.
  23. Longo D, Fauci A, Kasper D, Hauser S, Jameson J, Loscalzo J. *Harrison's Principles of Internal Medicine*. 18<sup>th</sup> ed. New York: McGraw-Hill; 2011.
  24. Ravichandran B, Krishnamurthy V, Ravibabu K, et al. Assessing dust exposure in an integrated iron and steel plant in south india. *Work* 2000;30:195-200.
  25. Rafei M, Gadgil AS, Ghole VS et al. Assessment of air pollution on the health status of the workers in beam rolling factory (Iran National Steel Industrial Group) from Ahvaz-Iran. *Indian Journal of Occupational and Environmental Medicine* 2009;13(1):20-22
  26. Antó JM, Vermeire P, Vestbo J, et al. Epidemiology of chronic obstructive pulmonary disease. *Eur Respir J*. 2001;17(5):982-94.