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Original Research Article

To Assess the Lung Function Status by Measuring Peak Expiratory Flow of the Goldsmiths Working in Chennai Central: A Cross-Sectional Study

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ABSTRACT

Background: Goldsmiths may be occupationally exposed to metal dust, fumes, and other airborne contaminants generated during jewellery manufacturing. Prolonged exposure to such occupational hazards may adversely affect respiratory function. This study assessed selected pulmonary function parameters among goldsmiths and compared them with jewellery shop workers who were not occupationally exposed to dust.
Methods: A cross-sectional comparative study was conducted among 200 participants, comprising 100 goldsmiths and 100 jewellery shop workers. Goldsmiths aged 20–50 years who had worked for approximately 10 hours per day for at least 5 years were included. Age-matched, healthy jewellery shop workers without occupational dust exposure served as controls. Individuals with respiratory infections, tuberculosis, cardiovascular disease, diabetes, hypertension, previous chest or abdominal surgery, neuromuscular disorders, spinal abnormalities, other systemic illnesses, or a history of smoking were excluded. Pulmonary function testing was performed in the morning in the sitting position using an Easy One™ diagnostic spirometer. Peak expiratory flow (PEF), forced expiratory flow at 25–75% of forced vital capacity (FEF25–75%), and maximum voluntary ventilation (MVV) were assessed. Continuous variables were summarized as mean ± standard deviation and compared using Welch's independent-samples t-test. A p-value <0.05 was considered statistically significant.
Results: Mean PEF was lower among goldsmiths than jewellery shop workers (457 ± 181 vs. 480 ± 73 L/min), although the difference was not statistically significant (p=0.20). FEF25–75% was significantly lower among goldsmiths (2.75 ± 1.42 vs. 3.43 ± 0.79 L/s; p<0.001). Similarly, MVV was significantly reduced among goldsmiths compared with controls (81 ± 25 vs. 113 ± 25; p<0.001). Among goldsmiths, participants with ≥15 years of occupational exposure had lower PEF and FEF25–75% than those with <15 years of exposure (p=0.05 for both), whereas the difference in MVV was not statistically significant (p=0.30).
Conclusion: Goldsmiths demonstrated reduced selected pulmonary function parameters, particularly FEF25–75% and MVV, compared with occupationally unexposed jewellery shop workers. These findings suggest an association between prolonged occupational exposure and

impaired respiratory function and support the need for appropriate workplace ventilation, respiratory protection, and periodic pulmonary function surveillance among goldsmiths.

Keywords: Occupational Exposure; Occupational Diseases; Pulmonary Function Tests; Peak Expiratory Flow Rate; Respiratory Function Tests; Lung Functions; Goldsmiths; Metal dust; Occupational hazards

INTRODUCTION

Jewellery designing, manufacturing, and trading have been integral components of human society for more than 5,000 years. India has been internationally renowned for its jewellery craftsmanship and diverse jewellery designs since ancient times. Historically, jewellery designing and manufacturing were largely undertaken by a limited number of families, with specialized technical knowledge closely guarded and traditionally transmitted across generations. Over time, however, the rapid expansion and commercialization of the jewellery industry have transformed this traditional occupation into a broader employment sector, creating opportunities for an increasing number of workers. Alongside this industrial growth, occupationally induced respiratory illnesses have been increasingly reported in various studies, particularly among workers exposed to hazardous substances in occupational settings. [1–3] Murgia et al. [4] demonstrated occupationally associated physiological alterations, particularly respiratory changes, among goldsmiths. Prolonged exposure to fine metallic dust generated during jewellery manufacturing, including dust from metals such as gold, silver, and platinum, may result in adverse respiratory effects and serious occupational health consequences. Previous reports have also indicated increased mortality from cancer among workers employed in the jewellery industry. [5,6]

The term metals generally refer to elements characterized by specific physical and chemical properties; however, a distinct boundary between metals and non-metals cannot always be established because certain elements, including arsenic (As), bismuth (Bi), germanium (Ge), antimony (Sb), selenium (Se), and tellurium (Te), commonly classified as metalloids, exhibit properties of both groups. Occupational exposure to acidic air and gaseous pollutants, including nitrogen oxides and sulfur oxides, has been implicated in respiratory pathophysiological changes and may contribute to conditions such as asthma and pulmonary carcinogenesis. [7] In this context, the present study was undertaken to investigate occupational respiratory hazards among goldsmiths, particularly those employed in the unorganized jewellery sector in Chennai. Exposure to fumes generated from various metals, acids, and gases has been associated with deterioration of pulmonary function among goldsmiths. [8] Furthermore, the high density of vehicular traffic in the central area of Chennai contributes to increased ambient air pollution. Goldsmiths working in this environment may therefore experience combined occupational and environmental exposure to airborne pollutants, potentially increasing their risk of respiratory impairment. Accordingly, goldsmiths working in the Chennai Central area were selected for the present investigation.

Pulmonary Function Test (PFT) is used to assess functional impairment or disability; follow up response to therapy, determine further treatment goals, severity, and estimate prognosis. [9] Pulmonary function testing is an important diagnostic tool for the objective assessment of respiratory function and provides quantitative measures of lung volumes, capacities, and airflow. Peak Expiratory Flow (PEF) is the lung function measurement that records the maximum speed at which one can forcefully exhale air from the lungs after taking a deep breath. PEF by definition is the highest expiratory flow attained during a forced expiratory maneuver starting from full inspiration. Forced Expiratory Flow at 25% to 75% (FEF 25-75) specifically measures the status of the smaller, medium to thin airways. FEF 25-75 by definition is the average forced expiratory flow during the middle half of the FVC, reflecting airflow through the medium and small airways. [10] This is also considered a highly sensitive indicator for early-stage lung disease, which was our main goal to detect earlier the pathology inside the lungs getting affected silently. This test is a non-invasive, simple procedure easily done to screen people for early detection of respiratory compromise.

Aim

The aim is to assess the lung function in goldsmiths exposed to various kinds of occupational dust and to find the lung functions of goldsmiths in terms of Peak Expiratory Flow (PEF), Forced Expiratory Flow at 25% to 75% (FEF25-75) with Maximum Voluntary Ventilation (MVV) and the objectives were to compare with the controls not exposed to these kind of metallic fumes in the same industry doing sales at Jewel Showrooms - Jewellery Shop workers along with correlation between respiratory parameters and duration of exposure to metal dusts.

MATERIALS AND METHODOLOGY

The prerequisites done were that the subjects were instructed to have a light breakfast, to avoid beverages before recording PFT and made comfortable by doing with the portable spirometer at their place. They were allowed to calm down, feel comfortable, and the procedure was explained in their own language. The complete explanation and multiple demonstrations of the procedure were done. The subjects were properly instructed and motivated.

Methodology: The sample size was 200, including 100 goldsmiths and 100 Jewellery Shop workers who were recruited from the Goldsmith Workers Welfare Association near Chennai Central and data were stored and analysed in the research laboratory, Institute of Physiology and Experimental Medicine, Madras Medical College, Chennai-3, after getting the institutional ethics committee approval. EC Reg.No.ECR/270/Inst./TN/2013. IEC.NO: 06062019. Surprisingly, all goldsmiths were males. Proper information and explanation to the study group was given and informed written consent was obtained. A brief history, including personal history, family history, and history of any previous illness of respiratory diseases or treatment for respiratory diseases, was noted. General and systemic examination was done thoroughly. PFT was performed using Easy One^{TM} Diagnostic Spirometer, in the sitting posture in the morning uniformly and compared with age matched gender matched controls chosen for the study by the inclusion criteria, which were in age group of 20 to 50 years. The goldsmiths by profession working for 10 hours/ day for at least 5 or more years and age matched healthy controls were selected for the study who were not exposed to any kind of dust at their work places – Jewellery Shop Workers**.** The exclusion criteria were subjects with a history of acute or chronic respiratory infections, tuberculosis, cardiovascular diseases, diabetes, hypertension, abdominal or chest surgery, neuromuscular diseases, abnormalities of the spine and any other systemic illnesses, and those with a history of smoking were excluded from the study. To perform peak expiratory flow rate test, the subject was asked to take a deep inspiration and then to blow hard into the mouth piece of the flow meter with a maximal forcible expiration. The movement of the needle on the PEFR dial indicator was expressed in litres/min. Three readings were taken at 1 minute interval and best value was noted down. The spirometer was calibrated by the standard procedures based on the American Thoracic Society (ATS) and European Respiratory Society (ERS) guidelines.

The parameters taken into our study were

1. **PEF (Peak Expiratory Flow)**
   The maximum flow rate achieved during forced expiration, occurring very early (first 100 ms) in the maneuver. It is largely effort-dependent and reflects the

calibre of the large/central airways (trachea, main bronchi) at high lung volumes. [10]

2. **FEF 25–75% (Forced Expiratory Flow, mid-expiratory phase)**
   The average flow rate over the middle half of the FVC maneuver (between 25% and 75% of FVC exhaled). It is relatively effort-independent and reflects the status of the small and medium-sized airways (bronchioles, less than 2mm diameter) — the classic "small airways" indicator. [11,12]
3. **MVV (Maximum Voluntary Ventilation)**
   The maximum volume of air a person can breathe in and out in one minute (typically measured over 12–15 seconds and extrapolated). It is a global/integrated test reflecting airway resistance across the entire bronchial tree, lung/chest wall compliance, respiratory muscle strength and endurance, and coordination of the whole ventilatory pump. As a rule of thumb, MVV correlates roughly with FEV1 × 35–40 (Guyton's approximation). [10]

Chronic inhalation of fine metal/mineral dust particles (occupational settings as mining, foundries, welding, stone-cutting, cotton dust, etc.) classically produces a small airways disease pattern before larger airway or restrictive changes become obvious. [13]

Statistical Analysis

Data were entered, stored, and analyzed using IBM SPSS Statistics version 24.0. Continuous variables were summarized as mean ± standard deviation (SD), while categorical variables, where applicable, were summarized as frequencies and percentages. Baseline characteristics and pulmonary function parameters were compared between goldsmiths and jewellery shop workers. For continuous variables, comparisons between the two independent groups were performed using Welch's independent-samples t-test. Pearson's chi-square test or Fisher's exact test was used, as appropriate, for comparisons of categorical variables. Among goldsmiths, pulmonary function parameters were additionally compared according to duration of occupational exposure (<15 years vs. ≥15 years) using the Welch independent-samples t-test. All statistical tests were two-sided, and a p-value <0.05 was considered statistically significant.

RESULTS

In the table 1, baseline characteristics of goldsmiths and jewellery shop workers were compared and found to be similar not showing any statistically significant differences. In table 2, the following spirometric parameters were only taken as PEF showed difference but not statistically different. The FEF 25-75 and MVV were very much decreased in goldsmiths, showing very significant statistical difference by the p value less than 0.001. In table 3, the PEF, FEF25-75 and MVV values in spirometry compared among goldsmiths with exposure more or equal to 15 years showed differences in all parameters being reduced who were exposed more than 15 years, but statistically significant only in PEF and FEF25-75 showing the real clinical importance of early small airway disease monitoring, which may become abnormal before FEV1, which was our prime focus in this study.

Table 1: Baseline Characteristics of Goldsmiths and Jewellery Shop Workers.

Variables	Goldsmiths (n = 100) Mean ± S.D	Jewellery Shop Workers (n = 100) Mean ± S.D	p value
Age (Years)	43 ± 10	42.86 ± 9	0.5^{ns}
Height (Meters)	1.63 ± 0.56	1.64 ± 0.6	0.7^{ns}
Weight (Kg)	59 ± 13	56 ± 9	0.5^{ns}
BMI(Kg/m²)	25.9 ± 4.4	24.4 ± 3.2	0.6^{ns}

ns – not statistically significant

Table 2: PEF and FEF 25-75 values between Goldsmiths and Jewellery Shop Workers:

Study Parameters	Goldsmiths (n = 100) Mean ± S.D	Jewellery Shop Workers (n = 100) Mean ± S.D	p value
PEF(L/min)	457 ± 181	480 ± 73	0.2^{ns}
Forced Expiratory Flow 25-75% (FEF 25-75) L/sec	2.75 ± 1.42	3.43 ± 0.79	< 0.001**
MVV	81 ± 25	113 ± 25	< 0.001**

p Value <0.001* - Very Significant, ns - not significant

Table 3: Comparison between PEFR, FEF 25-75%values and duration of exposure to metallic dusts in Goldsmiths:

Study Parameters	Duration of exposure <15years (n=39) Mean ± S.D	Duration of exposure ≥15years (n=61) Mean ± S.D	p value
PEFR(L/min)	482 ± 193	417 ± 15	0.05*
Forced Expiratory Flow 25-75% (FEF 25-75) L/sec	2.97 ± 1.45	2.41±1.31	0.05*
MVV	83 ± 24	78 ± 25	0.3^{ns}

p value ≤0.05* Significant

DISCUSSION

Positive health outcomes were observed more frequently among the exposed group than among their unexposed counterparts. To further assess respiratory health, physical examination was performed, with particular emphasis on peak expiratory flow rate (PEFR), forced expiratory flow at 25–75% of the pulmonary volume (FEF25–75%), and maximum voluntary ventilation (MVV). PEFR was not employed as a diagnostic measure for any specific pulmonary disease; rather, it was used as an indicator of overall pulmonary function. Because PEFR may be reduced in obstructive airway diseases, a low PEFR value can suggest subclinical or impending airway obstruction, as observed in conditions such as asthma, chronic bronchitis, and emphysema, or may indicate impaired respiratory function.

The study further revealed that most goldsmith workshops were characterized by high levels of dust, overcrowding, and inadequate ventilation. In several instances, workers also resided within or in close proximity to these crowded and poorly ventilated premises, resulting in considerable overlap between their occupational and residential environments. The study population working in goldsmith workshops consisted predominantly of male workers.

Pulmonary function testing (PFT) is an important component of the diagnostic evaluation of various respiratory disorders and is widely used to objectively assess pulmonary function. Although most PFT methodologies are well established and routinely employed in clinical and occupational settings, standardized testing procedures and quality-control measures are essential to ensure the reliability, reproducibility, and comparability of the results.

The exposure is typically associated with a confined workplace with very poor ventilation. The sulphuric and nitric acids at high temperatures with the various metals as gold, silver, cadmium. etc are gaseous forms SOx and NOx ie acids and fumes are hygroscopic and produce mist. A small amount of coal used in each unit and rice bran causes progressive respiratory impairment by airway obstruction.

The pathophysiology behind fine metal dust particles affecting lungs were diverse in nature incudes:

Determinants of Pathogenicity whether inhaled metal dust causes disease depend on several key physical and chemical factors:
Particle size - particles smaller than 5 microns (especially 1–3 microns) reach the alveoli gets settled down and slowly deposited, unlike the larger particles, which are trapped in the upper airways and cleared by mucociliary action.
Solubility - soluble metal particles dissolve and act more like a chemical or if in excess, become systemic toxin; insoluble particles persist and provoke chronic tissue reactions, especially inflammation.
Chemical reactivity - Each metal acts differently, while some metals are relatively inert (causing simple deposition), while others are fibrogenic or directly toxic.
Concentration and duration of exposure - cumulative dose over years of occupational exposure strongly influences disease severity. [14]

Major Pathological Categories
Pneumoconiosis (Dust Deposition Diseases)
Initially starts as asthma, converted into a benign course, and even ends up in carcinogenicity.
Fibrogenic Reactions
Metal dusts in jewel making includes mixture of various metals includes, especially when mixed with silica, which provoke fibroblast proliferation and collagen deposition, leading to progressive massive fibrosis in severe cases. The proposed mechanism are macrophages engulf particles which release cytokines (TNF-α, IL-1, TGF-β) leads to fibroblast activation and finally collagen deposition.
Metal Fume Fever is caused by inhalation of freshly formed oxide fumes (especially copper, magnesium) typically from welding or smelting operations. It presents as a flu-like illness 4–12 hours post-exposure, with fever, chills, myalgia, and leukocytosis. It is thought to result from the release of endogenous pyrogens from macrophages and epithelial cells reacting to metal oxide particles, and is usually self-limiting, resolving within 24–48 hours. [15]
Hypersensitivity / Immunologic Reactions can cause giant cell interstitial pneumonitis via a hypersensitivity-type mechanism or a chronic granulomatous lung disease resulting from a delayed-type (Type IV) hypersensitivity reaction; high-level exposure can also cause acute chemical pneumonitis. [14]
Carcinogenic Potential is associated with chromium VI compounds, nickel, cadmium, and arsenic - are associated with an increased risk of bronchogenic carcinoma with chronic exposure.
Inhalation of airborne particulate matter can induce a range of pathological changes in the respiratory system, including airway inflammation, destruction of pulmonary parenchyma, and recruitment of inflammatory cells and mediators. These effects may be mediated through several interrelated mechanisms, including protease–antiprotease imbalance and increased oxidative stress, ultimately contributing to progressive pulmonary injury. Occupational exposure to emissions generated during the melting of gold and its alloys may further contribute to respiratory morbidity. Such emissions may contain hydrocarbons and nitrogen oxides from petrol- and diesel-powered equipment, while sulphur dioxide released from gas-welding processes may add to the overall burden of respiratory pollutants. The potential health impact may be further amplified by the location of these workshops in densely populated and heavily trafficked areas, such as those surrounding Chennai Central.
Exposure to sulphur-containing pollutants has been associated with airway irritation, chronic bronchitic changes, and an increased propensity for bronchoconstriction. Compared with unexposed indoor office workers, goldsmiths may experience greater occupational exposure to particulate matter and redox-active compounds, which can promote oxidative stress and initiate a cascade of inflammatory responses. Persistent exposure may subsequently result in airway inflammation, partial airflow

obstruction, and alterations in pulmonary function.

At the level of the terminal bronchioles, inhaled particulate and chemical pollutants may induce the generation of reactive oxygen species (ROS), including through cytochrome P450 1A1 (CYP1A1)-related pathways, and activate downstream inflammatory signalling pathways involving cytokines, mitogen-activated protein kinases (MAPKs), and nuclear factor kappa B (NF-κB). Sustained activation of these pathways may contribute to chronic inflammation and structural and functional alterations of the respiratory tract and pulmonary tissues.

In the present study, goldsmiths demonstrated significantly lower peak expiratory flow rate (PEFR) values than the comparison group. This reduction may indicate the presence of airway inflammation and airflow limitation, particularly involve the tracheobronchial airways, and suggest that chronic occupational exposure to dust and other airborne pollutants may adversely affect respiratory function among goldsmith workers.

The sequence typically described in occupational medicine texts is as follows.

Small Airways are affected first on exposure to fine metallic dusts and fumes in goldsmiths on daily basis. Since particles in the 1–5 micron range penetrate deep into the bronchial tree and deposit at the level of terminal/respiratory bronchioles, the earliest physiological change is often a fall in FEF 25–75%, even when FEV1 and FVC are still within normal limits. This is why FEF 25–75% is often called the most sensitive early marker of small airways obstruction in occupational surveillance - it can be abnormal in workers who are otherwise "normal" by FEV1/FVC criteria.

PEF Is Relatively Preserved Early, Falls Later:

Because PEF depends on large airway calibre and expiratory effort, it tends to remain normal in early/mild disease. It only declines once there is more advanced airway narrowing, mucus plugging, or once central airway involvement/bronchospasm develops as in mixed exposures with irritant gases by the gold jewellery making, or once chronic bronchitis-type changes set in. PEF is more useful for serial monitoring (e.g., cross-shift or cross-week variation in cotton/textile workers - the classic "Monday morning" byssinosis pattern) than for detecting subtle baseline damage.

MVV declines as disease becomes more established:

MVV falls when there is a combination of increased airway resistance (from fibrosis, mucus, bronchospasm) plus reduced compliance and possibly respiratory muscle fatigue from chronic disease. A disproportionate fall in MVV relative to FEV1 can suggest additional factors like poor effort, neuromuscular involvement, or significant small airways contribution to overall resistance. It is a good integrated index of a worker's overall ventilatory reserve/exercise capacity - relevant for fitness-to-work assessments.

Stage	FEF 25–75%	PEF	MVV	FEV1/FVC
Early/subclinical small airways damage	↓ (earliest change)	Normal	Normal	Normal
Established obstructive disease	↓↓	↓	↓	↓
Advanced/mixed disease	↓↓↓	↓↓	↓↓	↓↓

This staged pattern is why occupational health surveillance protocols recommend including FEF 25–75% alongside standard spirometry, since relying on FEV1/FVC alone can miss early, reversible small-airway damage - the stage where intervention (exposure reduction, PPE, job rotation) is most effective. [10,13]

Subhabrata Moitra et al. reported that goldsmiths had a higher prevalence of respiratory disturbances and reduced pulmonary function compared with front-office staff. [17] Similarly, Rahman MM et al. reported that prolonged occupational exposure to gases and fumes was a significant risk factor for impaired pulmonary fitness and was associated with marked alterations in lung function among exposed workers. [18] Goldsmiths are primarily engaged in the manufacture of gold ornaments and may also work with silver articles and jewellery. Inhalation of silver-containing dust or fumes may result in deposition of silver particles within the alveolar and bronchial tissues; however, such deposition has not consistently been associated with clinically significant adverse health effects. [19,20] Nevertheless, studies among silver polishers have reported respiratory abnormalities, including bronchitis, emphysema, and reductions in pulmonary volumes following occupational exposure to metallic silver and other metals. [21] The duration and cumulative intensity of occupational exposure are important determinants when assessing the adverse effects of dust exposure on pulmonary function. Cumulative exposure to metal dust, together with longer job-specific employment duration, has been associated with a more pronounced decline in spirometric parameters. [22] Furthermore, increasing age, longer duration of mining experience, and greater cumulative exposure to respirable dust have been reported to be significantly associated with a higher prevalence of breathlessness. [23]

From our study, the analysis showed an overall reduction in peak expiratory flow (PEF) even though not statistically significant, a marked decrease in forced mid-expiratory flow ((FEF 25-75%)), and a reduced maximal voluntary ventilation (MVV) strongly pushes goldsmiths to compromised lung functions.

Limitations of study:

FEF 25–75% has high inter-individual variability and is very volume-dependent (affected by how hard the person inhales before exhaling), so single abnormal values are interpreted cautiously - trends over serial testing matter more. MVV is effort- and coordination-dependent, so a low MVV needs correlation with FEV1 to rule out poor patient effort versus true ventilatory impairment. In mixed-dust exposures (e.g., silica plus metal fumes), a restrictive component (fibrosis) can also develop, which affects FVC and total lung capacity independently of these flow-based measures so full interpretation needs the complete PFT panel (spirometry + lung volumes + DLCO) rather than these three parameters alone. [16]

CONCLUSION

Appropriate occupational safety measures should be implemented to minimize respiratory exposure among goldsmiths. The use of safety glasses, dust masks or appropriate respirators, face shields, gloves, and protective aprons, particularly during jewellery-making processes associated with metallic dust generation, should be encouraged. Adequate workplace ventilation should also be ensured through mechanical ventilation systems, such as exhaust fans, supplemented by natural ventilation through appropriately positioned doors and windows. Periodic breaks or exposure-free intervals should be incorporated into the work schedule, particularly during periods of reduced workload, to minimize prolonged and continuous exposure to metallic dust.

Annual health assessments should include regular respiratory evaluation, with simple spirometry incorporated into routine occupational health check-ups for goldsmiths. In addition to monitoring conventional spirometric parameters such as forced vital capacity (FVC), forced expiratory volume in the first second (FEV_1), FEV_1/FVC ratio, and maximum voluntary ventilation (MVV), greater attention should be given to peak expiratory flow (PEF) and forced expiratory flow at 25–75% of pulmonary volume ($FEF_{25–75}$%). These parameters may provide useful information regarding airflow limitation and small-airway involvement, which may become apparent before more pronounced changes are detected in FEV_1 or FVC. Occupational health education should be provided to workers, with emphasis on healthy lifestyle practices, avoidance of occupational exposures, and regular breathing exercises, including yoga-based respiratory exercises where appropriate. Overall, implementation of appropriate preventive, protective, and surveillance measures is essential for safeguarding the respiratory health of goldsmiths, and access to adequate occupational health and safety measures should be regarded as a fundamental component of worker protection.

Declaration by authors

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