MINISTRY OF HUMAN RESOURCES
DEPARTMENT OF OCCUPATIONAL SAFETY AND HEALTH

GUIDANCE ON SPIROMETRY PROCEDURE FOR OCCUPATIONAL HEALTH PRACTICE 2026

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i PREFACE

Occupational Lung Diseases (OLDs) pose persistent occupational health risks across major industrial sectors, necessitating rigorous health surveillance for underlying conditions including occupational asthma, silicosis, and chronic obstructive pulmonary disease (COPD). These diseases often progress silently, and their impact is frequently exacerbated by late diagnosis and inadequate health surveillance measures.

In response, the **Guidance on Spirometry Procedure for Occupational Health Practice** has been developed to provide a comprehensive framework for medical practitioners and occupational health professionals. This guidance aims to standardise spirometry practices across industries, ensuring that respiratory health assessments are conducted with the highest degree of accuracy and consistency.

Occupational health practitioners and employers are responsible for implementing effective medical surveillance programmes. This responsibility includes selecting the right equipment, ensuring personnel competency, and adhering to strict quality control protocols during testing. Failure to uphold these standards may lead to misdiagnosis, which can compromise employees' welfare and expose the organisation to legal non-compliance employee.

Adherence to this guidance supports the early detection of respiratory abnormalities, thereby protecting employees' lung health. It also offers tangible organisational benefits. Properly conducted spirometry identifies lung function decline before symptoms become irreversible, enabling timely intervention, reducing long-term healthcare costs, and helping to maintain a healthy and productive workforce.

This document outlines key strategies focused on technical competency, infection control, and the accurate interpretation of results based on the latest standards. Emphasis is placed on empowering healthcare providers with the knowledge to conduct valid assessments and manage data integrity effectively.

Occupational health practitioners are strongly encouraged to adopt and implement this guidance as an essential tool for safeguarding employee's health. Proper implementation will help ensure spirometry functions as a proactive screening tool for the early detection of occupational lung disease in Malaysia.

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Director General
Department of Occupational Safety and Health
2026

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iii TABLE OF CONTENTS

iv LIST OF ABBREVIATIONS

ATS/ERS	-	American Thoracic Society and European Respiratory Society
COPD	-	Chronic Obstructive Pulmonary Disease
DOSH	-	Department of Occupational Safety and Health
FEV_1	-	Forced Expiratory Volume in 1 Second
FVC	-	Forced Vital Capacity
TLC	-	Total Lung Capacity
ILO	-	International Labour Organization
ISO	-	International Organization for Standardization
OLD	-	Occupational Lung Disease
OSHA	-	Occupational Safety and Health Act
SME	-	Small and Medium Enterprise
WHO	-	World Health Organization

v LIST OF FIGURES & TABLES

List of Figures

List of Tables

vi TERMINOLOGY & DEFINITIONS

OLD	- Lung conditions that are caused or made worse by certain agents/materials at the workplace
Organic dust	- Airborne particles that originate from living sources, encompassing a variety of materials derived from plants, animals, and microorganisms
Occupational Asthma	- New onset asthma associated with the environment at the workplace
Occupational Disease	- Disease arising out of or in connection with work
Work Exacerbated Asthma	- Pre-existing non-occupational asthma but worsened by the workplace environment
Silicosis	- An irreversible but preventable lung disease, is caused by inhalation of respirable silica dust. Work exposures to silica dust also cause other serious diseases
FEV_1	- Amount of air can be forcefully exhaled in the first second after a deep breath
FVC	- Maximum total volume of air can be forcefully exhaled after taking the deepest breath as possible
Longitudinal Monitoring	- Refers to the continuous or repeated assessment of patients over an extended period to track changes, trends, and developments of health status in order to improve long-term outcomes

1.0 INTRODUCTION

The Guidance on Spirometry Procedure for Occupational Health Practice serves as a vital standardizing framework developed to combat the silent progression of Occupational Lung Diseases (OLDs) across industrial sectors. The primary purpose of this guidance is to establish clear, consistent, and uniform procedures for conducting and interpreting spirometry tests in accordance with the latest international standards.

1.1 Scope

The guidance is a resource on spirometry in occupational health practice, especially for occupational health doctors (OHD) and registered medical practitioner, outlining the overview of occupational lung diseases (OLD), its related legal provision, the requirements for employees' spirometry assessment and guidance on proper spirometry procedure.

1.2 Objectives

The objectives of the guidance are as follows:

A **Standardize Spirometry Practices**

Establish clear and consistent procedures for conducting and interpreting spirometry tests in occupational health settings in line with ATS/ERS guidelines.

B **Facilitate Early Detection and Monitoring**

Use spirometry to detect early signs of OLDs and monitor employees' respiratory health over time.

C **Support Regulatory Compliance and Employee Safety**

Ensure compliance with occupational health regulations while enhancing employees' safety through proactive spirometry-based surveillance.

D **Educate Healthcare Providers**

Provide training for healthcare professionals on proper spirometry techniques and result interpretation.


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2.0 LEGISLATIONS & STANDARDS

Health Surveillance On Employees At Risk Of Occupational Lung Diseases

Occupational health aims to prevent occupational diseases at the workplace. Efforts should be made to reduce the risk of developing occupational disease. The goal is early detection of disease, before the clinical symptoms appear or become irreversible. Good quality spirometry testing enables early detection of respiratory abnormalities, prompting timely intervention and treatment. It can detect changes in lung function before noticeable symptoms occur, allowing for preventive measures.

2.1 Legal Provisions

a. Occupational Safety and Health Act 1994

Duty to conduct and implement risk assessment

Section 18B. (1) *Every employer, self-employed person or principal shall conduct a risk assessment in relation to the safety and health risk posed to any person who may be affected by his undertaking at the place of work.*

(2) *Where a risk assessment indicates that risk control is required to eliminate or reduce the safety and health risk, the employer, self- employed person or principal shall implement such control.*

b. Occupational Safety and Health (Use and Standard Exposure of Chemicals Hazardous to Health) Regulations 2000

Regulation 2. Interpretation

"medical surveillance" means the monitoring of a person for the purpose of identifying changes in health status due to occupational exposure to chemicals hazardous to health;

Regulation 27. Health surveillance programme

(1) *Where an assessment indicates that health surveillance is necessary for the protection of the health of employees exposed or likely to be exposed to chemicals hazardous to health, the employer shall carry out a health surveillance programme.*

(2) *The medical surveillance component of the health surveillance programme in sub regulation (1) shall be carried out by an occupational health doctor.*

2.2 Industry Code of Practice

Industry Code of Practice on Safe Working in a Confined Space 2010

2.3.1 Part III Detail Requirements: Health Requirements of Person Working in Confined Space

The employer shall ensure that his authorised entrant intending to work in confined space are certified physically and mentally fit determined by an occupational health doctor (OHD). The examination may be tailored to detect various conditions of ill health, including chronic airway diseases such as asthma, bronchitis, or a shortness of breath on exertion.

2.3 Guidelines

Guidelines on Medical Surveillance Programme at the Workplace 2023

The need for spirometry testing, as part of the medical surveillance programme, is set out in the Guidelines on Medical Surveillance Programme at the Workplace 2023. Medical surveillance refers to systematic and periodic assessment of an employee's health status following exposure to chemicals hazardous to health, which may include biological monitoring, biological effect monitoring or health effects monitoring.

The General Guidelines (Part A) highlights spirometry as an investigation tool for the purpose of Health Effects Monitoring (HEM) of the respiratory system. Spirometry also forms part of the target organ function test under the General Medical Surveillance Procedures.

3.0 OCCUPATIONAL LUNG DISEASE: EPIDEMIOLOGY AND DISEASE BURDEN

Occupational Lung Diseases (OLDs) are a significant public health concern, representing a diverse group of respiratory diseases that arise from exposure to harmful agents in the workplace. These diseases among others are work-related asthma, hypersensitivity pneumonitis, pneumoconiosis, pleural mesothelioma and lung cancer. The burden of occupational lung disease is substantial, affecting not only the health and well-being of employees but also imposing economic costs on healthcare systems and industries.

OLDs are characterised by their causative relationship with occupational exposures, which include inhalation of dust, fumes, gases, and other harmful substances. The symptoms of these diseases often mirror those of non-occupational lung diseases, making accurate diagnosis challenging. The latency period for the onset of symptoms can vary significantly, with some conditions manifesting shortly after exposure while others may take years or even decades to develop. In addition to legal compliance, this variability underscores the need for heightened awareness and vigilance in occupational health practices.

3.1 Epidemiology

The epidemiology of OLDs reveals a complex interplay of factors, including the type of occupation, the nature of exposures, and individual susceptibility. Certain industries, such as construction, mining, and agriculture, are particularly associated with higher risks of lung disease due to the prevalence of hazardous materials like silica dust, asbestos, and organic solvents. In developed countries, work-related asthma has emerged as the most common chronic occupational lung disease, accounting for a significant proportion of asthma in adults. Meanwhile, conditions like silicosis and coal employees' pneumoconiosis, although declining in incidence due to improved occupational safety measures, still pose risks in certain sectors.

3.1.1 Global Epidemiological Data

ILO and WHO have been instrumental in highlighting the prevalence and burden of these diseases globally. According to recent estimates, more than 10% of all lung diseases are attributed to occupational exposures, with COPD and occupational asthma being the most prevalent forms of OLDs. The WHO reported that in 2019, chronic respiratory diseases, excluding lung cancer and infections, caused approximately 4 million deaths globally and accounted for 103.5 million disability-adjusted life years (DALYs). Additionally, the ILO has emphasized that respiratory diseases, particularly pneumoconiosis and silicosis, remain among the leading causes of work-related morbidity and mortality, affecting millions of employees worldwide.

3.1.2 Epidemiology in Malaysia

In Malaysia, a total of 870 respiratory disease cases were reported to DOSH between 2011 and 2024. The burden of OLDs is increasingly recognised, particularly in industries such as manufacturing and construction. Recent data from the Ministry of Health Malaysia indicates that approximately 10% of employees in these sectors exhibit symptoms of chronic respiratory conditions, with silicosis being one of the most frequently diagnosed diseases.

A study conducted from 2020 to 2023 found that the incidence of occupational asthma in Malaysia is approximately 2 to5 cases per 100,000 employees annually, highlighting a growing concern for respiratory health. Industrial regions such as the Klang Valley, Penang, and Johor, along with agricultural zones in Sabah and Sarawak, are hotspots for such diseases. The prevalence of Occupational Respiratory Disease among Malaysian employees is around 8.7%. This rate is substantially higher than the global incidence of occupational asthma but is lower than the prevalence reported among industrial employees in other countries, such as Ethiopia (51.6%), the UK (22%), and Bangladesh (34%).

3.2 The Burden of Disease

The burden of OLDs extends beyond individual health impacts; it encompasses economic implications as well. The costs associated with medical treatment, loss of productivity, and compensation claims can be substantial. Moreover, the chronic nature of many OLDs often leads to long-term disability, further exacerbating the economic toll on both affected individuals and society at large. The World Health Organization and other health agencies recognise the importance of addressing occupational health risks to mitigate these burdens.

3.2.1 Burden of Occupational Lung Disease (OLD) in Malaysia

The burden of OLDs in Malaysia can be understood through its impact on public health, the economy, and the healthcare system.

In 2022, 1,797 cases were referred for opinion regarding employment injury and invalidity, with 80.7% completion, while 655 cases were referred for opinion concerning Occupational Diseases with 83.5% completion rate for PERKESO claims. In 2022, 489 cases were referred for Medical Assessment.

Public Health Impact

i. **Workforce Disability**
OLDs are a leading cause of disability among employees in affected industries. Chronic conditions like pneumoconiosis and COPD can lead to permanent impairment, forcing employees out of the labour market and creating a significant economic burden.

Economic Burden

i. Lost Productivity

The economic impact of OLDs is substantial due to lost workdays, reduced productivity, and early retirement. Employees with chronic respiratory conditions often require extended sick leave or are unable to perform their jobs effectively, leading to decreased output in critical industries.

ii. Healthcare Costs

The treatment and management of OLDs place a significant strain on the healthcare system. The chronic nature of many OLDs often leads to long-term disability. Long-term care for chronic conditions, frequent hospitalisations, and the need for specialised respiratory treatments increase healthcare costs. This burden is exacerbated by the need for ongoing monitoring and rehabilitation for affected employees.

iii. Compensation and Legal Costs

Employees with occupational diseases are entitled to compensation under Malaysia's Employees' Social Security Act 1969. The cost of compensation claims, coupled with legal expenses in cases of disputed claims, adds to the economic burden on employers and the state.

Social and Economic Implications

i. Family Impact

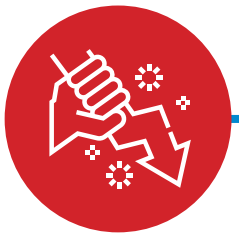
Families of affected employees often face financial difficulties due to the loss of income and increased healthcare costs. The long-term disability associated with OLDs can lead to significant socioeconomic challenges for households.

ii. National Economic Impact

The broader economic impact includes reduced productivity across key sectors, higher healthcare expenditure, and a strain on social security systems due to increased claims for disability and health related compensation.

3.2.2 Employers and Hiring Companies

The disease burden of Occupational Lung Diseases (OLDs) on employers and hiring companies in Malaysia is significant, affecting various aspects of business operations, from productivity and financial performance to compliance with regulations and reputation management. Here's a detailed breakdown:



Productivity Losses

i. **Reduced Workforce Efficiency**
Employees with OLDs often experience chronic symptoms such as breathlessness, fatigue, and reduced lung function, which can significantly impair their ability to perform physically demanding tasks. This leads to lower productivity levels, especially in industries that rely on manual labour, such as construction, manufacturing, and mining.

ii. **Increased Absenteeism**
Employees suffering from OLDs are likely to take more sick leave, particularly during periods of exacerbation or when seeking medical treatment. Chronic conditions like COPD or occupational asthma can lead to frequent and prolonged absences, disrupting workflow and project timelines.

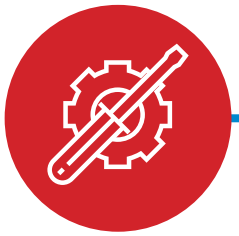
iii. **Workforce Attrition**
In severe cases, employees may need to retire early or leave the workforce due to disability caused by OLDs. This attrition not only leads to a loss of skilled and experienced employees but also necessitates the hiring and training of new employees, which can be costly and time-consuming.

Financial Costs

i. **Healthcare and Compensation Expenses**
Employers in Malaysia are legally required to bear the costs of medical treatment and compensation for employees who suffer from occupational diseases. This includes paying for ongoing medical care, rehabilitation, and possibly long-term disability benefits. The financial burden can be substantial, especially for SME.

ii. **Legal and Insurance Costs**
Companies may face legal challenges from affected employees seeking compensation for their illness, especially if the disease was caused by negligence or failure to adhere to safety regulations. Legal fees, settlements, or court-ordered compensations can add to the financial strain. Additionally, companies might see increased insurance premiums due to claims related to occupational diseases.

iii. **Loss of Revenue**
The cumulative effect of reduced productivity, absenteeism, and workforce attrition can lead to significant revenue losses. Companies may fail to meet production targets or contractual obligations, leading to penalties, loss of business opportunities, or damage to customer relationships.



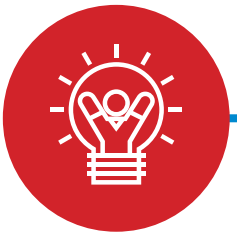
Operational Challenges

i. **Disruption in Operations**
When key employees are affected by OLDs, it can disrupt business operations, particularly in industries where skilled labour or specialised knowledge is required. Replacing affected employees temporarily or permanently can be challenging, especially in sectors facing labour shortages. The absence of experienced employees can delay projects, reduce the quality of work, and necessitate costly overtime for remaining employees to meet deadlines.

ii. **Increased Operational Costs**
To mitigate the impact of OLDs, employers may need to invest in additional safety measures, equipment, and training. This can include improving ventilation systems, providing protective gear, and conducting regular health surveillance and workplace assessments. These costs, while necessary for compliance and employee protection, can add to the overall operational expenses. Moreover, companies might need to implement modifications in workflow or processes to accommodate affected employees, which can lead to inefficiencies and higher costs.

iii. **Challenges in Workforce Management**
Companies might face difficulties in workforce management, such as reallocating tasks among remaining employees or managing shifts to cover for absent employees. This can strain human resources and management, leading to potential burnout and reduced morale among unaffected employees. In the long term, this can impact employee retention and increase turnover rates, further exacerbating workforce challenges.

These operational challenges, if not properly managed, can significantly affect a company's efficiency and profitability, highlighting the importance of proactive occupational health management and robust employee safety programmes.



Mitigation Strategies and Proactive Measures

While the burden of OLDs on employers is significant, there are proactive measures that companies can take to mitigate these impacts:

i. **Investing in Employees' Health and Safety**
When companies prioritise employees' health and safety through investment in protective equipment, improved ventilation systems, regular health screenings, and training programmes, they can reduce the incidence of OLDs and, consequently, the associated burdens.

ii. **Early Detection and Intervention**
Implementing regular health surveillance programs can help detect early signs of OLDs, allowing for timely intervention and potentially preventing the progression of the disease. Early detection can reduce the need for long-term medical care and help maintain employee productivity.

iii. **Employee Education and Training**
Providing ongoing education and training on the risks of exposure, reporting early symptoms and the proper use of protective equipment can empower employees to take an active role in protecting their health, reducing the likelihood of developing OLDs. It also fosters a culture of health vigilance in workplaces.

iv. **Collaboration with Health Authorities**
Engaging with health authorities, such as the Ministry of Health and DOSH, to stay updated on the latest guidelines and regulations can help companies stay compliant and adopt best practices in occupational health.

v. **Transparent Communication and Reporting**
Maintaining transparency in communication with employees about health risks and safety measures, as well as accurate and timely reporting to authorities, can build trust and improve compliance.

Employers can reduce the burden of OLDs while also improving overall business resilience, employee well-being, and long-term profitability by adopting these strategies.

3.3 The Use of Spirometry in Reducing OLDs

3.3.1 Compliance and Risk Reduction for Employers

Employers can meet medical surveillance guidelines through the use of spirometry, which demonstrates active surveillance and mitigation of respiratory risks. This reduces legal liability and insurance costs while improving workplace reputation.

3.3.2 Early Detection and Diagnosis

Promoting the use of spirometry enables early detection of lung function abnormalities before symptoms emerge. Many OLDs like silicosis and work- related asthma progress silently in their early stages. Regular spirometry screenings, especially in high-risk sectors (e.g., construction, mining, manufacturing), allow healthcare providers to identify declines in lung function early and initiate timely interventions.

3.3.3 Targeted Intervention and Management

Early detection through spirometry allows employees to be removed from further exposure to workplace hazards, and workplace control measures can be improved to prevent disease progression. This proactive approach reduces long-term disability and enhances treatment outcomes.

3.3.4 Baseline and Periodic Monitoring

Establishing baseline spirometry values and conducting periodic assessments help in tracking changes in lung function over time. Such surveillance is crucial in high-exposure occupations, ensuring any deterioration is promptly addressed through medical or occupational interventions.

4.0

OVERVIEW OF OCCUPATIONAL LUNG DISEASES

4.1 Introduction

Occupational Lung Diseases (OLDs) are caused by long-term exposure to certain irritants present at the workplace. In some conditions, the agents/materials existing at individuals' working areas may worsen the preexisting lung condition.

The International Labour Organisation (ILO) has highlighted the critical importance of addressing OLDs, which represent a major occupational health challenge affecting millions of employees worldwide.

Of particular concern is pneumoconiosis, a disease caused by inhaling dust, especially silica and asbestos. The ILO International Classification of Radiographs of Pneumoconiosis provides a standardised approach for diagnosing and monitoring pneumoconiosis. This classification system facilitates international comparisons and epidemiological research, enabling better tracking of disease prevalence and the effectiveness of preventive measures. The ILO has also initiated the Global Programme for the Elimination of Silicosis, aiming to eliminate this preventable disease by 2030, which underscores the organisation's commitment to improving occupational health standards.

In summary, OLDs represent a significant public health issue that requires concerted efforts from health professionals, policymakers, and industries to prevent and manage. The ILO's initiatives and the extensive knowledge found in occupational medicine literature provide essential frameworks for addressing these diseases and protecting the respiratory health of employees globally.

4.2 Types Of Dust

4.2.1 Organic Dust

Organic dust is a complex mixture that includes viable and non-viable microorganisms such as bacteria, fungi, and their metabolites, alongside plant debris, animal dander, and other organic materials. The composition of organic dust can vary significantly depending on the source, but it generally includes components like pollen, mold spores, animal hair, feathers, and organic matter from decomposing plant and animal materials.

a. Sources of Organic Dust

Organic dust is prevalent in various occupational settings, particularly in agriculture, where activities such as grain handling, livestock management, and waste processing generate significant amounts of dust. For instance, agricultural employees are often exposed to high concentrations of organic dust from grains, hay, and animal bedding, which can contain harmful microorganisms and allergens. Other industries, such as textiles and woodworking, also contribute to organic dust exposure through processes that involve natural fibres and materials.

b. Health Impacts of Exposure to Organic Dust

Exposure to organic dust is associated with a range of adverse health effects, particularly respiratory conditions. Common health issues linked to organic dust exposure include:

- **Occupational Asthma**: Chronic exposure to certain organic dusts can lead to the development of asthma symptoms, particularly in employees exposed to wood dust or grain dust.
- **Chronic Respiratory Diseases**: Long-term exposure to organic dust can contribute to chronic bronchitis and other obstructive lung diseases, exacerbating existing respiratory conditions and leading to significant health deterioration over time.
- **Organic Dust Toxic Syndrome (ODTS)**: A non-infectious febrile illness characterised by flu-like symptoms, which can occur after exposure to high concentrations of organic dust, often seen in agricultural settings.
- **Hypersensitivity Pneumonitis**: An immunological response to inhaled organic dust, leading to inflammation of the lung tissue. This condition can be triggered by exposure to mouldy hay or other organic materials.

4.2.2 Inorganic Dust

Inorganic dust is airborne particulate matter composed primarily of non- carbon-based materials derived from mineral, metallic, or chemical sources. Unlike organic dust, it does not originate from living organisms and is commonly generated through mechanical processes like crushing, grinding, and mining.

Inorganic dust is a major occupational health hazard because the particles, especially when respirable (less than 10μm in diameter), can penetrate deep into the lungs. They are poorly cleared, leading to retention, inflammation, and scar tissue formation. The most hazardous forms of silica and asbestos fall into this size range.

a. Sources Of Inorganic Dust

The main types include Siliceous Dust, such as Crystalline Silica (Quartz) from rock, granite, and concrete, and Coal Dust, both of which can cause severe lung scarring. Another major source is Fibrous Dust like Asbestos, which is a carcinogen. Finally, Metallic Dusts (e.g. nickel, cadmium) are generated during welding and metal fabrication, posing both lung and systemic toxicity risks. In short, inorganic dust is durable, non-carbon- based, and retains its physical form to cause long-term damage once inhaled.

b. Health Impacts of Exposure to Inorganic Dust

Exposure to inorganic dust poses severe health risks, primarily impacting the respiratory system by causing fibrosis and cancer.It can also also lead to systemic toxicity when heavy metals are involved. The risk is greatest for respirable dust, which penetrates to the alveoli and cannot be effectively cleared. Common health issues linked to inorganic dust exposure include:

i. **Chronic Obstructive Pulmonary Disease (COPD)**
   Long-term exposure to many types of inorganic dust (e.g., coal dust, silica, cement dust) can lead to Chronic Bronchitis and Emphysema, causing irreversible airflow limitation.

ii. **Pneumoconiosis**
   A group of non-curable occupational lung diseases where inhaled mineral particles accumulate and cause scarring.

iii. **Lung Cancer**
   Specific inorganic dusts (e.g., Silica, Asbestos) are known to be carcinogenic.

iv. **Systemic Toxicity (Heavy Metal Dusts)**
   Dust from heavy metals (eg., Lead, Cadmium, Manganese) can be absorbed from the lungs into the bloodstream, affecting other organs.

4.3 Common Occupational Lung Diseases

4.3.1 Work-Related Asthma

Work-related asthma is an obstructive lung disease in which inhalation of an agent/ substance found in the workplace causes cascades of inflammatory and/or allergic reactions resulting in swelling and narrowing of the airways. Work-related asthma consists of both Occupational Asthma and Work Exacerbated Asthma. Occupational Asthma can be further divided into allergic or irritant-induced occupational asthma, as different causative agents lead to different pathophysiology and mechanisms of response in the body.

Certain agents and substances found in specific industries commonly trigger occupational asthma, including both immune-mediated and non-immune-mediated forms. The list of common causative agents and substances by specific industry and occupation is as follows:

Table 1: Agents causing occupational asthma

Agents/substances	Industry	Occupation
Enzymes	Service	Manufacturing washing powder
Aliphatic polyamines	Manufacturing	Manufacturing chemicals
Wood dust	Forestry	Sawmill
Chromium	Manufacturing	Electroplating activities
Aluminium	Manufacturing	Soldering
Glutaraldehyde	Healthcare	HCW endoscopy unit involve with cleaning medical equipment
Isocyanates	Chemical industry	Coating substance manufacture
Latex	Healthcare	Healthcare employees
Flour	Agriculture Food and beverages industry	Bakers and millers

4.3.2 Hypersensitivity Pneumonitis

Hypersensitivity pneumonitis is a reversible interstitial lung disease which may lead to progressive pulmonary fibrosis. Causes include infectious agents; enzymes; animal, insect and plant proteins; low-molecular-weight chemicals and metals.

Table 2: Agents and occupation associated with hypersensitivity pneumonitis

Disease	Exposure	Occupation
Animal handlers' lung	Dust of hair particles, dried urine of rats	Animal handler
Bagassosis	Mouldy sugar cane	Farmer
Bird fanciers' lung	Droppings and feathers	Bird farmer
Farmers' lung	Mouldy hay, straw, grain	Farmer
Maple bark strippers' disease	Mouldy maple bark	Forestry
Mushroom workers' lung	Mouldy mushroom compost	Farmer
Sequoiosis	Mouldy sawdust	Forestry
Wheat weevil lung / Miller's lung	Mouldy grain, flour, dust	Flour factory worker

4.3.3 Pneumoconiosis

Pneumoconiosis is a form of interstitial lung disease caused by breathing in certain types of dust. This dust settles deep in the lungs and causes an inflammatory reaction and damage to the lung tissue. Depending on the type of dust, the most common pneumoconiosis is coal workers' pneumoconiosis, also known as black lung disease.

Pneumoconiosis can also be categorised into simple and complex forms according to the severity of the lung disease. In simple pneumoconiosis, a small scar resembling a thick nodule is observed on the patient's chest x-ray, while in complicated pneumoconiosis, the patient's chest x-ray exhibits massive scarring in the lungs. This is a form of restrictive lung disease.

Table 3: Common type of pneumoconiosis, agents/dust and associated occupation

Type of pneumoconiosis	Agent/dust	Occupation
Black Lung disease (CWP)	Coal	Coal miners
Brown Lung (Byssinosis)	Cotton fibres	Cotton mill workers
Silicosis	Silica dust	Construction workers
Asbestosis	Asbestos	Construction workers
Siderosis	Iron dust	Welders
Hard metal pneumoconiosis	Cobalt/tungsten	Carbide exposed workers

4.3.4 Mesothelioma

Mesothelioma is a rare cancer arising from the membrane lining the lungs and abdomen, caused by exposure to asbestos. The most common types are pleural and peritoneal mesothelioma, while pericardial and testicular mesothelioma are rarely seen. The latency period for mesothelioma is approximately 25 to 50 years after the initial asbestos exposure.

Certain occupations have higher risk of asbestos exposure such as construction workers, drywall installers, factory workers, insulators, miners, painters, plumbers, shipbuilders, carpenters and mechanics.

4.3.5 Lung Cancer

Lung cancer is a leading cause of cancer-related morbidity and mortality globally. Occupational exposure to carcinogens is a well-established risk factor, particularly in certain industries and job roles.

Table 4: Agents and occupations associated with lung cancer

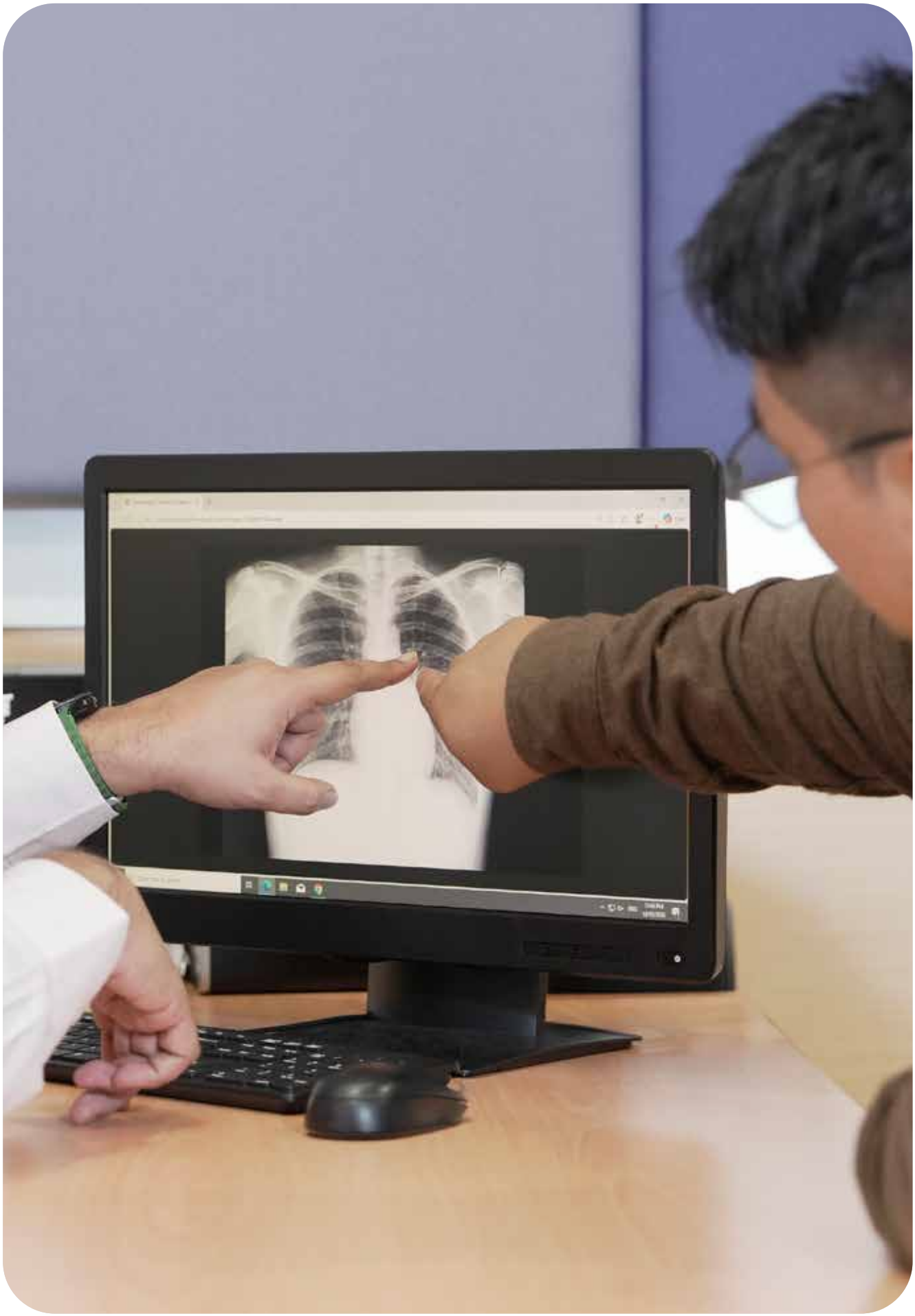
Agents/ substances	Industry	Occupation
Asbestos	• Constructions • Shipbreaking, Shipbuilding and Repair • Manufacturing	• Constructions workers Shipbreaking worker Shipbuilding Insulation workers • Automotive mechanics
Respirable Crystalline Silica	• Construction - Stone Cutting and Masonry, Concrete work, Demolition • Mining Industry – Quarrying, Sand and Gravel Mining • Manufacturing – Glass Production, Ceramics and Pottery	• Construction workers • Mining Workers • Manufacturing workers
Benzene	• Petrochemical Industry • Plastics and Polymers industry • Pharmaceutical Rubber Industry Agricultural Chemicals	• Chemical Engineers Industrial Chemists • Pharmacologists and Pharmaceutical Chemists • Environmental Scientists

Agents/ substances	Industry	Occupation
Formaldehyde	• Manufacturing – Resins, Plastics, Textiles and wood products • Medical and Laboratory settings • Agriculture • Construction Building material • Automotive Industry	• Manufacturing workers • Laboratory workers • Pesticide applicators • Construction Workers • Mechanics
Arsenic	• Agriculture • Mining and Metallurgy Wood Preservation Glass and Ceramics Electronics • Pharmaceuticals	• Farmers Miners • Glass makers • Related industry workers
Vinyl Chloride Monomer (VCM)	• Plastic and Polymer Industry • Construction Medical • Packaging Industry • Automotive Industry	• VCM Production Workers • Chemical Engineers • Construction Workers
Chromium (VI)	• Metal and Plating Industry • Welding and Fabrication Chemical Manufacturing Textile	• Chromium Platers • Welders and Cutters Welders • Fabricators • Chemical Plant workers • Textile Tanners
Cadmium	• Agriculture • Wood Preservation Mining and Metallurgy Electronics • Glass Manufacturing Pharmaceuticals	• Farmers • Related industry workers • Welders and Cutters Miners • Metallurgist

Agents/ substances	Industry	Occupation
Lead	• Battery Manufacturing and Recycling • Construction Smelting and Refining	• Technicians • Remolders Painters • Lead smelters
Polycyclic Aromatic Hydrocarbons (PAHs)	• Oil and Gas Industry • Coal and Tar Manufacturing • Road Construction • Metal Industry • Tobacco Industry	• Drillers and Refining Workers • Coal Tar Distillation, Gasification and Liquefaction Workers • Road Construction Workers • Aluminium Smelters, Welders and Cutters • Tobacco Industry Workers
Ionizing Radiation	• Medical and Healthcare Research	• Radiologists and Related Healthcare Workers • Researchers and technicians

1. **Chemical Carcinogens**
   Benzene, formaldehyde, and diesel exhaust are notable carcinogens found in various industrial settings. Benzene is used in petrochemical industries, formaldehyde in manufacturing and health care, and diesel exhaust in transportation and construction.

2. **Ionising Radiation**
   Exposure to ionising radiation, such as in medical radiography or nuclear industries, increases lung cancer risk. Radiation can cause direct DNA damage and increase mutation rates in exposed tissues.



5.0 SPIROMETER AND PERSONNEL

5.1 Introduction

Spirometry evaluates airflow through the conducting airways, including upper airway, trachea, bronchi, and bronchioles. It does not directly measure alveolar gas exchange, pleural function, or chest wall mechanics.

Spirometry should be performed according to internationally recognized ATS/ERS technical standards to ensure valid, reproducible and clinically interpretable results.

Commonly used parameters obtained from the test include the forced expiratory volume in one second (FEV_1), the forced vital capacity (FVC), and the FEV_1/FVC ratio.

In addition to numerical values such as FEV_1, FVC, FEV_1/FVC ratio, and peak expiratory flow, spirometry provides graphical outputs including the flow–volume curve and the volume–time curve. The quantitative and graphical data enable assessment of ventilation abnormalities and evaluation of test quality.

Spirometry can identify a restrictive ventilatory pattern but cannot diagnose restrictive lung disease. Confirmation requires measurement of static lung volumes (TLC).

In occupational health, spirometry is an essential tool for the assessment and surveillance of employees exposed to respiratory hazards such as dust, fumes, and chemicals. It enables early detection of changes in lung function and supports longitudinal monitoring.

Serial spirometry performed using the same equipment and quality standards provides greater value than isolated measurements when monitoring occupational lung function decline.

5.2 Choosing The Right Spirometer Equipment For Spirometry Tests

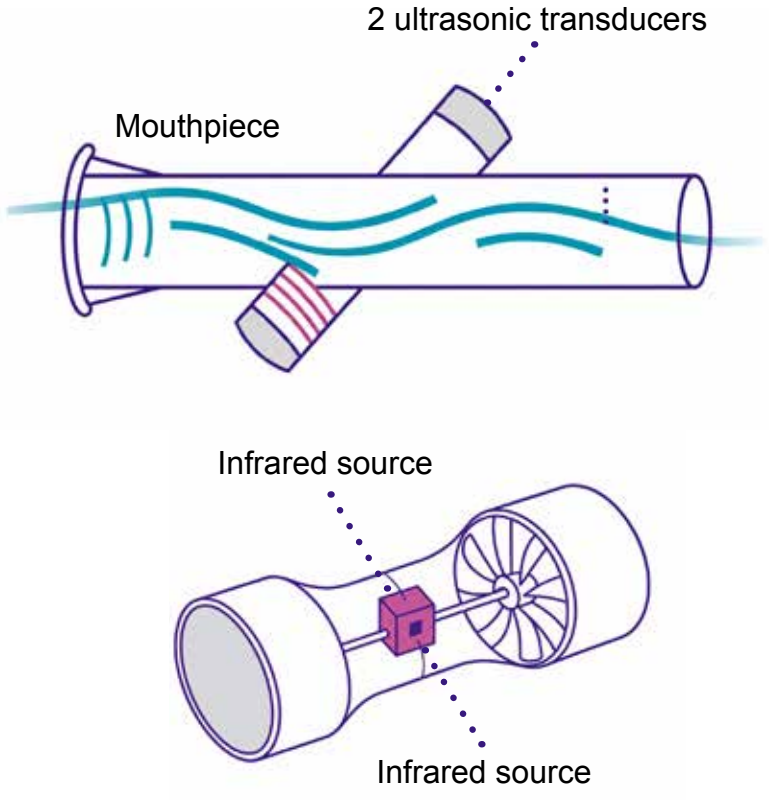
There are four factors to consider before choosing the spirometer. These are:

1. Types of spirometers
2. Spirometer performance
3. Software capability
4. Calibration and quality assurance requirements

5.2.1 Types of Spirometers

Spirometers are broadly categorised into Volume-displacement spirometers, which measure volume directly; and Flow-sensing spirometers, which calculate volume by integrating measured flow.

Flow-sensing spirometers (e.g., pneumotachographs, turbines, mass-flow devices, ultrasonic sensors) are commonly used in clinical and occupational health settings due to their portability and minimal moving parts (Figure 1).



Turbine spirometer

Figure 1: Flow-sensing spirometers

5.2.2 Minimum requirements of a spirometer

- All spirometers used should comply with ISO 26782 (spirometry equipment standards), and registered with Medical Device Authority (MDA), Ministry of Health (MOH), Malaysia. This information is available in the Malaysia Medical Device Register (MMDR), at the official website of MDA.
- The selection of spirometers should be based on accuracy, reliability, maintenance requirements and the needs of workplace health services.
- An ideal spirometer must meet international performance standards and support high-quality spirometry essentials for surveillance programmes.

a. Performance criteria

The spirometer must:

- Be able to accumulate volume continuously for ≥15 seconds,
- Have capacity for ≥8 L total volume,
- Have a functional flow range of 0–14 L/s,
- Have a real-time display of both flow–volume and volume–time curves, and
- Be able to store raw data at least 8 manoeuvres per session, with a minimum of 3 acceptable curves stored for reporting,
- The spirometer software should automatically identify unacceptable manoeuvres and provide real-time quality feedback to the operator.

b. Quality assurance and correction factors of software

- The software must perform automatic quality checks of each expiratory manoeuvre.
- All reported values must be corrected to BTPS (Body Temperature, Ambient Pressure, Saturated) using manufacturer-specified algorithms.

c. Calibration verification

- Spirometer calibration verification is the process of ensuring that a spirometer accurately measures lung function by comparing its readings to a known standard, typically using a certified calibration syringe.
- It is important in maintaining the accuracy and reliability of spirometry tests.
- For most spirometers (except Ultrasonic type), each system must include the 3-L syringe calibration. The calibration syringe must have an accuracy of ±0.015 L (0.5% of full scale) and be kept at room temperature with the spirometer.
- A calibration verification is the procedure used to validate that the device is within calibration limits (i.e.3% accuracy tolerance) .
- These requirements help to ensure that spirometry results are accurate and consistent.

5.3 Personnel Involved In Spirometry

5.3.1 General Requirements

5.3.1.1 Spirometry shall only be performed by trained and competent healthcare personnel.

5.3.1.2 Personnel should be healthcare professionals with appropriate medical training such as Occupational Health Doctors (OHDs), nurses and medical assistants.

5.3.1.3 As spirometry is an effort-dependent test, operators must be able to provide proper instruction and coaching, identify technical errors, and apply acceptability and repeatability criteria to ensure reliable results.

5.3.2 Training and Competency

5.3.2.1 Healthcare personnel involved in spirometry must have healthcare or medical background and demonstrate competency in preparing the employee for testing, performing spirometry according to recognised standards, and maintaining equipment quality control, including calibration procedures.

5.3.2.2 It is strongly recommended that the personnel have attended and completed a DOSH-recognised spirometry training programme to ensure standardised practice in Malaysia.

5.3.3 Personnel Categories and Roles in Spirometry

Two main categories of personnel are involved:

1. Spirometry Technicians
2. Occupational Health Doctors (OHDs)

Spirometry Technicians are responsible for the operational aspects of spirometry including:

- maintaining calibration and quality control records,
- preparing and instructing employees to achieve optimal test performance
- conducting spirometry according to recognised standards,
- identifying technical errors or suboptimal manoeuvres,
- determining whether results meet ATS/ERS acceptability and repeatability criteria.

OHDs are responsible for ensuring that spirometry performed for screening and surveillance complies with the latest recognized ATS/ERS quality standards. Their roles include:

- responsibilities as the Spirometry Technicians
- interpreting spirometry results, and
- integrating the findings with overall employee’s presentation and occupational health assessment.

6.0 BEST PRACTICE OF SPIROMETRY

6.1 Indications in Occupational Health Settings

Spirometry is an essential tool for the assessment and surveillance of employees exposed to respiratory hazards such as dust, fumes, and chemicals. However, spirometry must not be used independently to establish a diagnosis of lung disease.

Common indications in Occupational Health settings include:

1. **Pre-Employment Screening**
    - To establish baseline lung function before an employee is exposed to chemical or respiratory hazards.
2. **Annual Medical Surveillance**
    - To detect early decline in lung function among employees exposed to respiratory hazards.
    - To facilitate longitudinal monitoring.
    - To assess whether an employee is medically fit to wear a respirator during medical surveillance
3. **Evaluation of Respiratory Symptoms**
    - To assess for possible occupational asthma, COPD or other work-related respiratory diseases.
4. **Fitness-to-Work Assessment for Competent Persons Registered with DOSH**
    - To evaluate whether an employee has sufficient pulmonary reserve to safely perform duties in confined or oxygen-limited environments.
    - To assess whether a competent person is medically fit to wear a respirator.
    - To support health evaluations for individuals appointed as “competent persons” under DOSH regulations, depending on their work duties and exposure risks.

6.2 Contraindications

According to the ATS/ERS 2019 Standardisation of Spirometry, there are no absolute contraindications to spirometry. All contraindications are considered relative, and testing may be postponed rather than cancelled, depending on clinical judgement. The relative contraindications include:

a. Conditions associated with increased myocardial demand or changes in blood pressure:

- Acute myocardial infarction within 1 week
- Systemic hypotension or severe hypertension
- Significant atrial/ventricular arrhythmia
- Non-compensated heart failure
- Uncontrolled pulmonary hypertension
- Acute cor pulmonale
- Clinically unstable pulmonary embolism
- History of syncope related to forced expiration/cough

b. Conditions associated with increased intracranial/intraocular pressure

- Cerebral aneurysm
- Brain surgery within 4-week
- Recent concussion with continuing symptoms
- Eye surgery within 1 week

c. Conditions affecting sinus and middle ear pressures

- Sinus surgery or middle ear surgery or infection within 1 week

d. Conditions associated with Increased-intrathoracic and intra-abdominal

- Presence of pneumothorax
- Thoracic surgery within 4-week
- Abdominal surgery within 4-week
- Late-term pregnancy

e. Infection control issues

- Active or suspected transmissible respiratory or systemic infection, including tuberculosis
- Physical conditions predisposing to transmission of infections, such as haemoptysis, significant secretions, or oral lesions or oral bleeding

6.3 Quality Control

Reliable and accurate measurements are essential in occupational health surveillance, where results are used to monitor lung function over time and to detect early changes that may be related to workplace exposure.

An OHD must establish a standardised quality control protocol in his/her place of practice. Quality control in spirometry involves several key components e.g.:

1. Spirometer equipment maintenance.
2. Infection control.
3. Spirometry manoeuvres quality

6.3.1 Quality Control for Spirometer

6.3.1.1 Daily calibration verification must be performed at low, medium, and high flows using a 3-L syringe.

6.3.1.2 Testing must not proceed if the test fails, and any errors must be rectified first.

6.3.1.3 The same type of bacterial and viral filter (BVF) used for spirometry test should be included during calibration verification.

6.3.1.4 Recalibration verification is required after any failed attempt and in accordance with the manufacturer's recommended schedule.

6.3.1.5 Conduct routine preventive maintenance as recommended.

6.3.1.6 Ultrasonic spirometers do not require routine daily calibration verification with a 3-L syringe. However, they must undergo regular calibration and quality control checks in accordance with the manufacturer's instructions.

6.3.2 3-L Calibration Syringe

6.3.2.1 Daily inspection for correct piston stop-position is required and smooth piston movement with no sticking should be confirmed.

6.3.2.2 The manufacturer must verify syringe accuracy of ±0.015 L at recommended intervals.

6.3.2.3 Do not proceed with the spirometry test if the calibration verification test fails.

6.3.2.4 Check for leaks, loose connections, or dirt in the sensor.

6.3.2.5 Repeat calibration verification until all parameters are acceptable.

6.3.2.6 Leak testing should be performed monthly.

6.3.3 Documentation

6.3.3.1 OHD must designate a responsible person (e.g., trained spirometry operator, laboratory supervisor, or appointed quality control officer) to oversee equipment calibration, calibration verification, and maintenance.

6.3.3.2 A dedicated spirometry quality control log must be maintained.

6.3.3.3 This log should document daily calibration verification results, equipment repairs, adjustments, component replacements, software or firmware updates, and confirmation of correct reference values following any software changes.

6.3.3.4 Record the results of daily calibration verification tests (Pass/Fail and volumes) in the Logbook. This is to prove that the spirometer machine is calibrated routinely.

6.3.4 Biological Control (Optional but Recommended)

A biological control is a healthy, non-smoking individual who performs repeatable daily or weekly spirometry to detect equipment problems.

6.3.4.1 The results should be consistent over time; significant variation may indicate potential equipment or procedural issues.

6.3.4.2 Biological control testing is supplementary and does not replace routine calibration or verification using a 3-L syringe.

6.3.5 Infection Control Measures in Spirometry

Infection control is an essential component of safe spirometry practice, as spirometry test is an aerosol generating procedure.

6.3.5.1 Proper infection-prevention procedures help to reduce the risk of transmitting respiratory pathogens between employees and testing personnel.

6.3.5.2 All spirometry personnel should adhere to device-specific cleaning protocol provided by the manufacturer and follow established public health recommendations when conducting spirometry in occupational health settings.

6.3.5.3 Infection control procedures should include:

6.3.5.3.1 cleaning and disinfection of spirometers,

6.3.5.3.2 using disposable filters,

6.3.5.3.3 practising hand hygiene, and

6.3.5.3.4 ensuring proper ventilation in the testing environment.

6.3.5.4 Employees with acute respiratory infection symptoms should have spirometry deferred to reduce transmission risk of infection.


THE
HUMAN SKELETON

7.0 SPIROMETRY MANOEUVRE

Spirometry technique described in this chapter is adapted from ATS/ERS Task Force Standardisation of Spirometry (2005), Standardization of Spirometry 2019 Update (An Official American Thoracic Society and European Respiratory Society Technical Statement and the updated ATS/ERS Spirometry Technical Standards (2020).

7.1 Step-by-Step Guide to Performing a Spirometry Manoeuvre

Performing a high-quality spirometry manoeuvre requires correct preparation, clear instructions, and proper coaching throughout the test. The steps below outline the standard to ensure acceptability, repeatability, and employee's safety.

Step 1: Demonstrate the manoeuvre

- Ensure that the spirometer has been calibrated and verified for the day.
- Employee seat comfortably, with feet flat on the floor and his/her back supported.
- Attach a clean, disposable mouthpiece to the spirometer.
- Ask the employee to sit upright, place the nose clip securely, and listen carefully to instructions.
- Demonstrate the manoeuvre.

Step 2: Maximal Inspiration

- Instruct the employee to inhale fully, taking the deepest breath possible to reach total lung capacity.

Step 3: Mouthpiece Placement

- The employee should immediately place the mouthpiece in their mouth, ensuring a tight seal with lips around the mouthpiece to prevent air leakage.

Step 4: Forced Expiration

- Instruct the employee to blow out as hard, fast, and completely as possible, continuing without hesitation.
- Emphasise that the first second must be forceful to obtain an accurate FEV_1 measurement.

Step 5: Continued Exhalation

- The employee should continue exhaling until no more air can be expelled, typically for at least 6 seconds, or longer if required for complete emptying.
- Coaching (e.g., "keep going, keep blowing") is important to ensure full effort.

Step 6: Inspiration (if required)

- For a flow-volume loop assessment, the employee will be instructed to perform a rapid, maximal deep inhalation immediately after completing forced exhalation.

Step 7: Repeat Manoeuvres

- The manoeuvre should be repeated at least 3 times, allowing short rest between attempts.
- Up to 8 attempts may be performed if needed to achieve acceptable and repeatable results according to ATS/ERS criteria.

Step 8: Data Recording

- The spirometer records parameters such as FVC, FEV_1, FEV_1/FVC ratio, and flow–volume and volume-time curves for analysis.

Step 9: Quality Check

- Review each manoeuvre for acceptability (no cough, leaks, hesitation)
- Ensure the best two values for FEV_1 and FVC are within the repeatability criteria.
- If the acceptability and repeatability criteria are not met, additional coaching and attempts may be required.

7.2 Spirometry Techniques and Curves

Spirometry can be performed using the closed-circuit or open-circuit methods. In the closed-circuit method, the patient breathes into a sealed system, where exhaled gases are recirculated and measured directly. In contrast, the open-circuit method utilises a flow-based measurement using sensors (Figures 2 and 3).

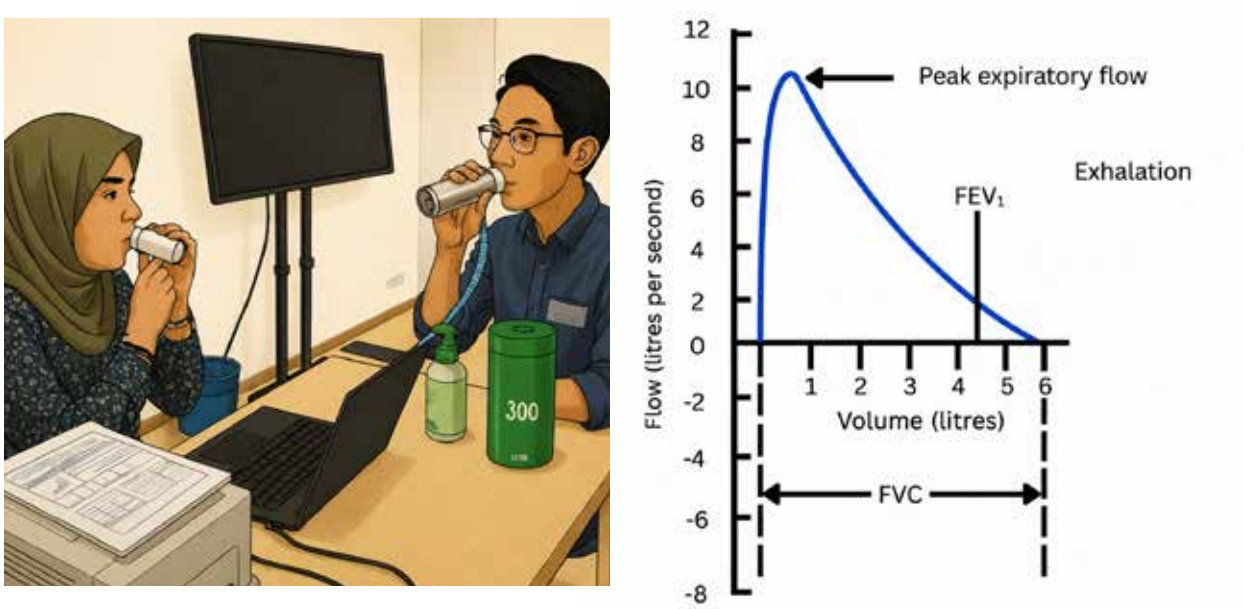


Figure 2: Open-circuit Spirometry spirogram (Flow volume curve)

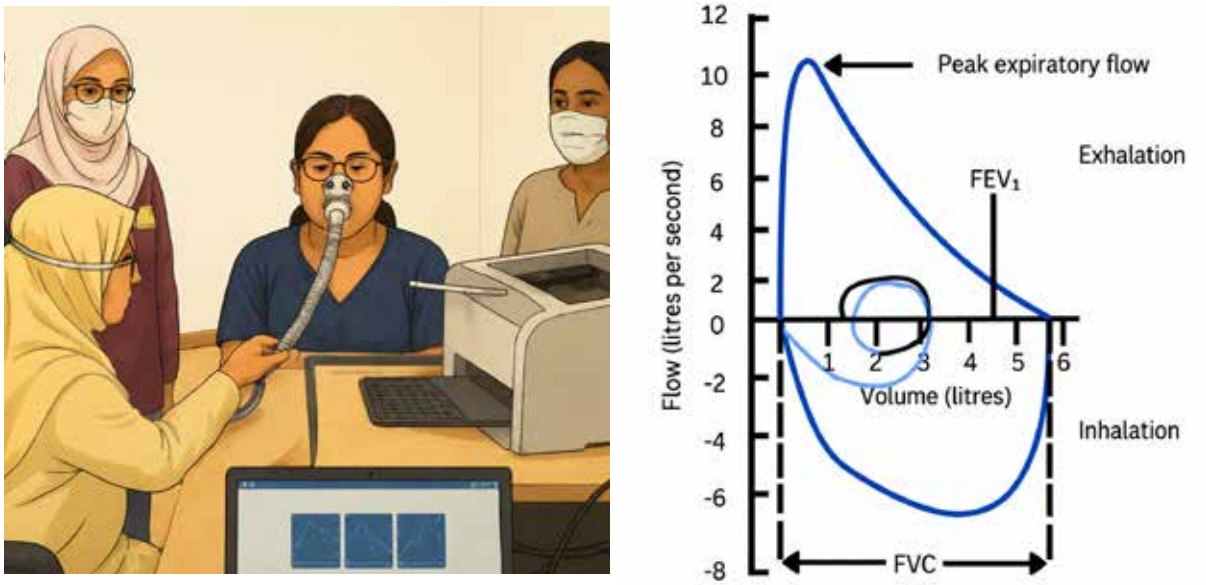


Figure 3: Closed-circuit spirometry spirogram (Flow volume curve)

7.3 ATS/ERS Guideline on Spirometry Acceptability and Repeatability Criteria

A spirogram is often displayed as a flow-volume curve and volume- time curve. **A flow volume curve** is a graph plotting lung volume against time, which shows how the volume of air exhaled or inhaled changes over time during a forced breathing manoeuvre (Figure 4). The normal volume-time curve shows a rapid rise that levels off to a plateau as the lungs are emptying (Figure 5).

A volume-time curve is a graph plotting lung volume against time, which shows how the volume of air exhaled or inhaled changes over time during a forced breathing manoeuvre. The normal volume-time curve shows a rapid rise that levels off to a plateau as the lungs are emptying. Most air is expelled within the first second, which indicates healthy and efficient lung function. Exhalation should continue until one of the three End of Forced Expiration (EOFE) criteria is met.

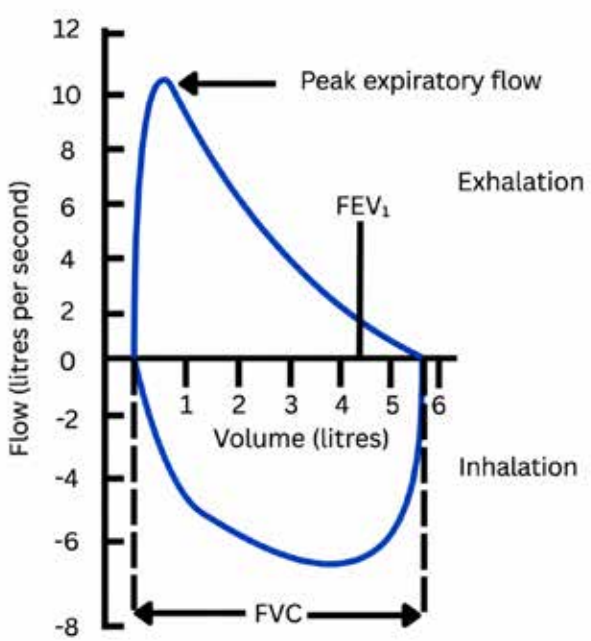


Figure 4: A flow-volume curve
(Source: MTS-MOH Spirometry Certification Programme)

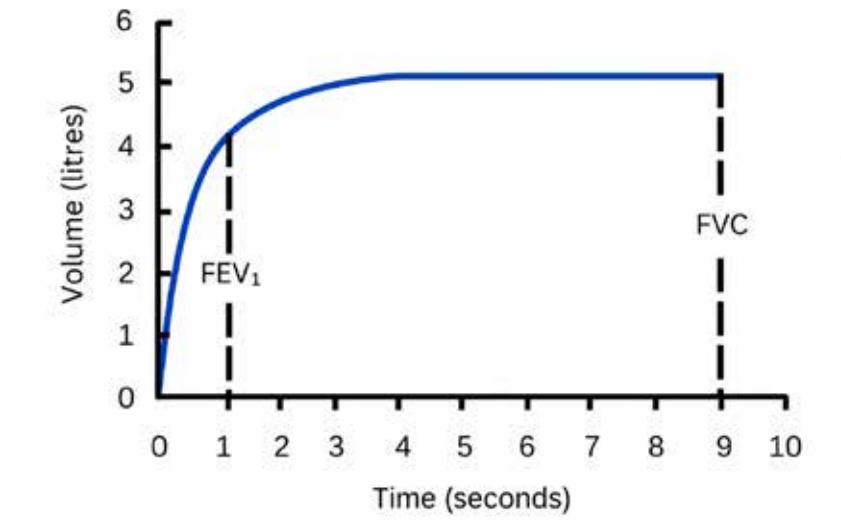


Figure 5: Normal volume-time curve showing a rapid rise of exhalation volume to a plateau and exhalation time of 6 seconds or more.
(Source: MTS-MOH Spirometry Certification Programme)

i. The Volume Plateau (Most Preferred)

This is the "gold standard" for a completed test. The software identifies a plateau when:

- There is < 0.025 L (25 mL) of air exhaled over the last 1 second.
- Essentially, the machine detects that the lungs are sufficiently empty, with virtually no more air coming out.

ii. The 15-second Limit

In patients with severe airflow obstruction (such as advanced COPD), air leaves the lungs so slowly that they might never reach a true volume plateau despite maximal effort.

- The forced expiratory manoeuvre may be terminated after 15 seconds of continuous forced exhalation.
- Continuing exhaling longer than 15 seconds is unlikely to provide additional clinically useful information and may increase the risk of adverse events such as dizziness or fainting (syncope)

iii. Repeatability (when a volume plateau cannot be reached)

If a patient cannot reach a plateau and cannot reach 15 seconds (perhaps due to discomfort or dizziness):

- The test can be considered "usable" if the FVC (Forced Vital Capacity) is repeatable (within 0.150 L of the previous best effort) or
- is greater than the largest prior observed FVC.

Acceptability criteria for spirometry ensure that the test results are both reliable and valid. These criteria focus on three distinct phases of the breath: the **Start**, the **Middle** (**Course**), and the **End**.

If a manoeuvre fails these, it may be labelled as "Unacceptable" or "Usable" depending on which rule was broken.

1. The Start of the Manoeuvre (The "Blast")

The goal here is to ensure the patient didn't hesitate and gave a maximal explosive effort.

- **Back-extrapolated volume/Extrapolated volume (BEV/EV):** Back-extrapolated volume/Extrapolated volume (BEV/EV): This measures "hesitation" at the start. The BEV must be ≤ 5% of the FVC or 0.100 L, whichever is greater. This is normally calculated automatically by the spirometer software (Figure 6).
- **Sharp peak**: There must be a rapid rise to the Peak Expiratory Flow (PEF) without any evidence of a "slow start."

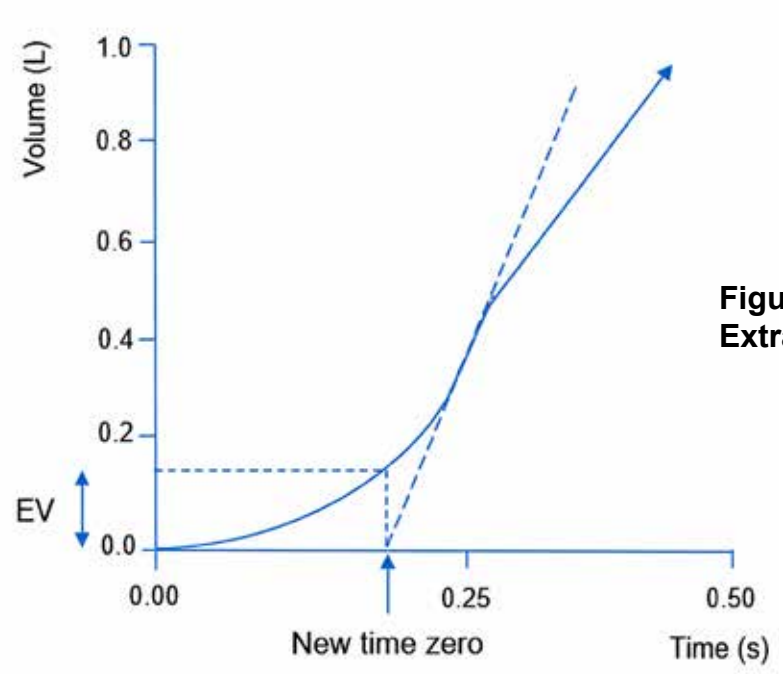


Figure 6: Calculation of Back Extrapolated Volume (BEV or EV)

2. The course of the manoeuvre (The "Flow")

The software looks for physical artifacts that could ruin the math of the test.

- **No coughing**: There must be no cough in the **first second** of expiration. A cough later in the breath is acceptable for FEV_1 but might invalidate the FVC.
- **No glottic closure**: The patient must not suddenly close their vocal cords, which causes an abrupt stop in flow.
- **No leaks**: There should be no air escaping around the mouthpiece.
- **No obstructions**: The patient's tongue or teeth should not block the flow of air.

3. The End of forced expiration (EOFE)

- **The manoeuvre** must meet one of the three criteria as spelt out above.

The 2019 update also introduced a **"Usable" category** to ensure that useful data from patients who encounter difficulty in obtaining an acceptable test is not discarded(such as the frail individuals or those in pain).

The employee should follow the correct technique, which includes taking a full inhalation, creating a tight seal around the mouthpiece, and performing a fast and unhesitant forced exhalation. Specific criteria must also be met regarding the extrapolated volume and the end of exhalation. The spirometry must be conducted without any obstruction or leak, with the patient not coughing, talking, or pausing during the exhalation.

Repeatability criteria are established to ensure that the spirometry results are consistent and reliable across multiple attempts. Employees must perform at least three acceptable spirometry tests, using the same technique each time, and the flow patterns should not show significant variations.

It is important for employees to follow instructions consistently during each spirometry, with a short rest period of at least 30 seconds between manoeuvres to avoid fatigue and maintain the quality of the spirometry. For spirometry results to be considered repeatable, the two largest values of FVC and FEV_1 from at least three acceptable attempts should be within 150 mL.

Examples of unacceptable manoeuvres are as in the Case Illustration.

7.4 Bronchodilator Responsiveness Test

The 2021/2022 ERS/ATS Interpretive Strategies marked a significant change in how **bronchodilator responsiveness (BDR)** is performed and calculated.

The key alteration is the transition from measuring the absolute volume difference to calculating the percentage change in FEV_1 or FVC relative to the predicted value for the respective parameter.

The current standard protocols for performing the test are as follows:

a. The Pre-Test Phase

Before the test begins, the patient's current bronchodilator must be withheld, depending on the type of bronchodilator they are taking. This is to ensure the baseline is accurate.

- SABA (e.g., Salbutamol): Withhold for 4 – 6 hours.
- SAMA (e.g., Ipratropium): Withhold for 12 hours.
- LABA (e.g., Salmeterol/Formoterol): Withhold for 24 hours.
- LAMA (e.g., Tiotropium/Glycopyrronium/Umeclidinium): Withhold for 36–48 hours.

b. Step-by-Step Procedure

1. **Baseline Spirometry**: Perform a standard spirometry test to obtain at least three acceptable and repeatable manoeuvres.
2. **Medication Administration**: Administer 400 µg of Salbutamol. (This is typically performed as 4 separate 100 µg puffs, using a spacer device if inhalation technique is unsatisfactory.)
3. **The Wait Time**: Wait for 15 to 30 minutes for the medication to reach full effect.
4. **Post-Test Spirometry**: Repeat the spirometry test, again aiming for three acceptable and repeatable manoeuvres.

c. The New "Positive Response" Calculation

- Under the new guidelines, the "12% and 200 mL" rule is no longer applicable. Instead, the percentage of change compared to the **Predicted Value** (using GLI-2012 equations) is used.
- **Positive Result**: An increase in either FEV_1 or FVC >10% relative to the predicted value.
- **Example**: The patient's Predicted FEV_1 **= 3.00 L**

  Pre-BD: **1.50 L** and Post-BD: **1.85 L**
- **Calculation**: $\frac{1.85 - 1.50}{300} \times 100\% = 11.6\%$
- **Result**: This is a **Positive** response (since **11.6% is > 10%**).

8.0 SPIROMETRY RESULT INTERPRETATION

Spirometry should be conducted only by spirometry-trained health/medical personnel and requires considerable effort and cooperation from the subject. As such, it is essential to examine whether the test results meet the acceptability and repeatability criteria before interpreting them. Insufficient effort from the subject can lead to misleading conclusions.

Therefore, spirometry results should always be interpreted in light of the overall clinical picture, including symptoms, occupational exposure and relevant medical history.

8.1 Normal Spirometry Values

The recorded spirometry values are compared to a range of values derived from a normal healthy matching population. Traditionally, percentage values of <80% predicted for FEV_1 or FVC are considered abnormal, while ratio values of FEV_1/FVC<70 indicate airflow obstruction.

However, these thresholds may lead to inaccuracies, which may result in under-diagnosis of obstructive airflow conditions in younger individuals and over-diagnosis in older individuals.

The Global Lung Function Initiative (GLI) provides universal, multi- ethnic reference equations for spirometry and is recommended for clinical use. The Lower Limit of Normal (LLN) is a threshold defined by GLI (typically the 5th percentile) to distinguish between normal lung function and potential restriction or obstruction.

8.2 Stepwise Interpretation Strategy (ATS/ERS 2022)

Before interpreting spirometry results, it is essential to confirm that the test meets quality standards for both acceptability and repeatability, as outlined in the quality control section. The manoeuvres should satisfy the required technical criteria to ensure the measurements are reliable and reproducible. If the test does not meet these standards, the results should not be interpreted, and the procedure should be repeated if possible.

Step 1: Check FEV_1/FVC against LLN

Is FEV_1/FVC < LLN?

- Yes → Obstructive pattern

Consider bronchodilator testing (if indicated).

- No → proceed to Step 2

Step 2: If ratio is normal, check FVC

Is FVC < LLN?

- Yes → Possible restrictive pattern

Confirm with TLC (full lung function).

Spirometry alone cannot confirm restriction ventilation.

- No → proceed to Step 3

Step 3: If both are normal

$FEV_1/FVC \geq LLN$ **and** $FVC \geq LLN$ → Normal spirometry

Step 4: Mixed pattern If BOTH are low:

- $FEV_1/FVC < LLN$ **and** $FVC < LLN$

→ Mixed obstructive + restrictive pattern

- Confirm restriction with TLC

Step 5: Assess Bronchodilator Responsiveness (ERS/ATS 2022)

A significant bronchodilator response is present when the change in FEV_1 or FVC is greater than 10% of its predicted value.

8.3 Abnormal Spirometry

Abnormal spirometry can be detected from the spirometry values or the trend of the spirometry values over time.

a. Abnormal spirometry values

Z-scores indicates how far an observed lung function value deviates from the predicted value, after taking into account factors such as gender, age, height, and ethnicity, and are expressed in standard deviations.

This method is recommended for determining the limit of normality and for assessing the degree of lung function impairment. A predicted value has a z-score of zero, and the fifth percentile corresponding to a z-score of < -1.64, is designated as the LLN.

The algorithm shown is used to classify the employee as having (Figure 7):

- Obstructive pattern (airflow obstruction)
- Possible restrictive pattern
- Possible mixed pattern with both obstructive and possible restrictive patterns
- Normal spirometry results

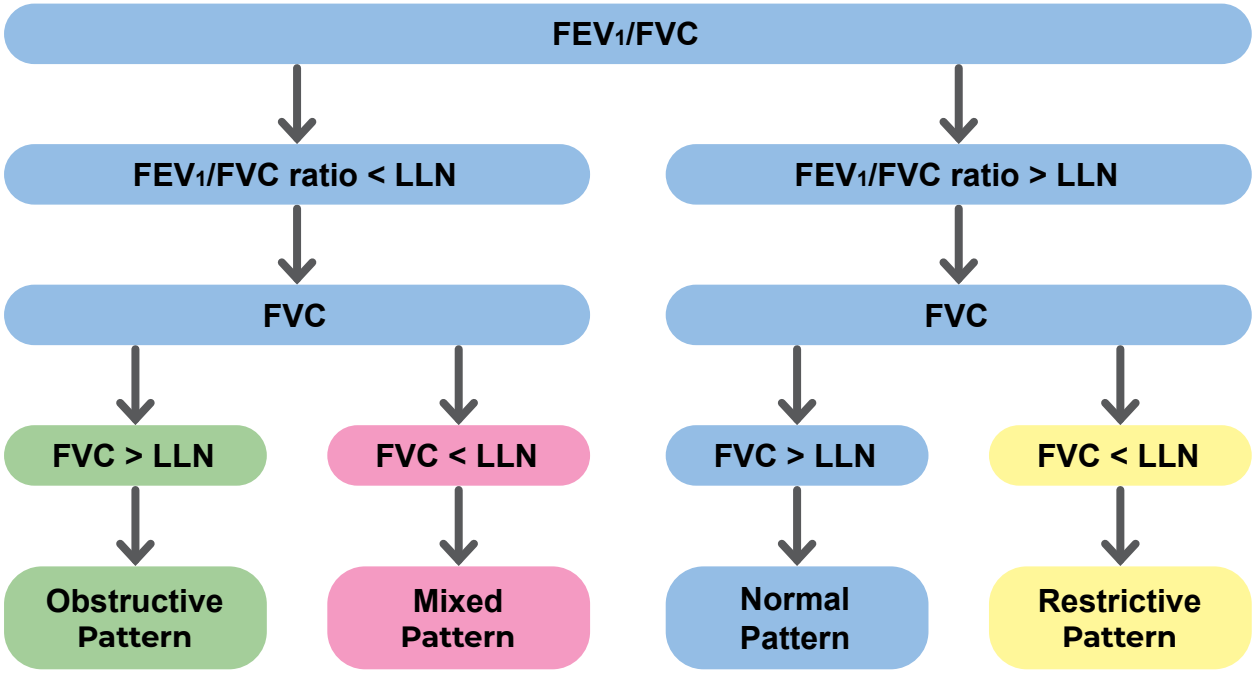


Figure 7: Approach to Spirometry interpretation with LLN values.

b. Abnormal trend of spirometry values

- Natural changes in lung function over time are key indicators of lung health. In non-smokers, FEV_1 typically decreases by approximately 30 ml per year.
- Clinically, >10% change in FEV_1 from baseline over the course of a year is considered significant for healthy individuals
- Some employees may initially have FVC and FEV_1 values that exceed their predicted ranges but can still experience a significant decrease in lung function due to occupational exposure or underlying health conditions.
- Employees must be referred to a physician for further evaluation if their spirometry results indicate any of the following:
    1. A restrictive or mixed pattern, which necessitates a full lung function test to confirm the presence of restrictive disease.
    2. A declining trend in values, despite initially normal results, specifically an annual reduction of 10% or more.
    3. Abnormal spirometry results.
    4. Symptomatic employee who is unable to perform acceptable spirometry.

9.0 SPIROMETRY REPORT

A spirometry report by a qualified medical doctor is required at the end of the test. For the purpose of this guidance, the OHD is responsible for the preparation of this report.

9.1 Key Components of a Spirometry Report

A report should consist of the employee's identifier, biological parameters, the spirometry results and interpretation.

a. Employee's identifier

1. Name
2. Ethnic
3. Gender
4. Age (Date of Birth)
5. Work place(site)

b. Biological parameters

1. Smoking status (including electronic cigarette)
2. Duration of smoking (years)
3. Height (metre)
4. Weight (kg)

c. Spirometry test

1. Date
2. Time
3. Indication (e.g. pre-placement, periodic surveillance, symptomatic evaluation)

d. Spirometry results

1. FVC (Forced Vital Capacity)
   All attempts or at least 3 acceptable readings
2. FEV_1 (Forced Expiratory Volume in 1 Second)
   All attempts or at least 3 acceptable readings
3. FEV_1/FVC Ratio
   The best reading of FEV_1 and FVC
4. Flow-Volume and Volume time curves
5. Bronchodilator Responsiveness (if necessary)

e. Results Interpretation based on Lower Limit Normal(LLN)

1. Normal spirometry
2. Obstructive Ventilatory defect/pattern
3. Restrictive Ventilatory defect/pattern
4. Mixed Ventilatory defect/pattern

f. Technical Comments

1. Name of spirometry technician
2. Technical report during the test
3. Name of the reporting OHD and affiliation
4. Date of report

9.2 Normal and Abnormal Spirogram

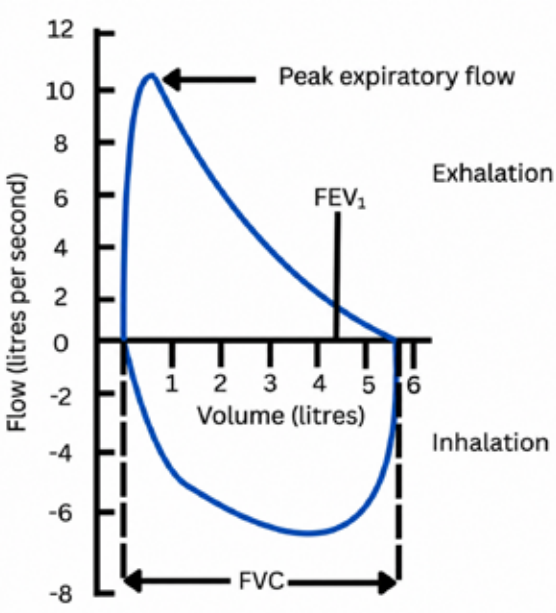


Figure 4: Normal Flow-volume curve (closed circuit)
(Source: MTS-MOH Spirometry Certification Programme)

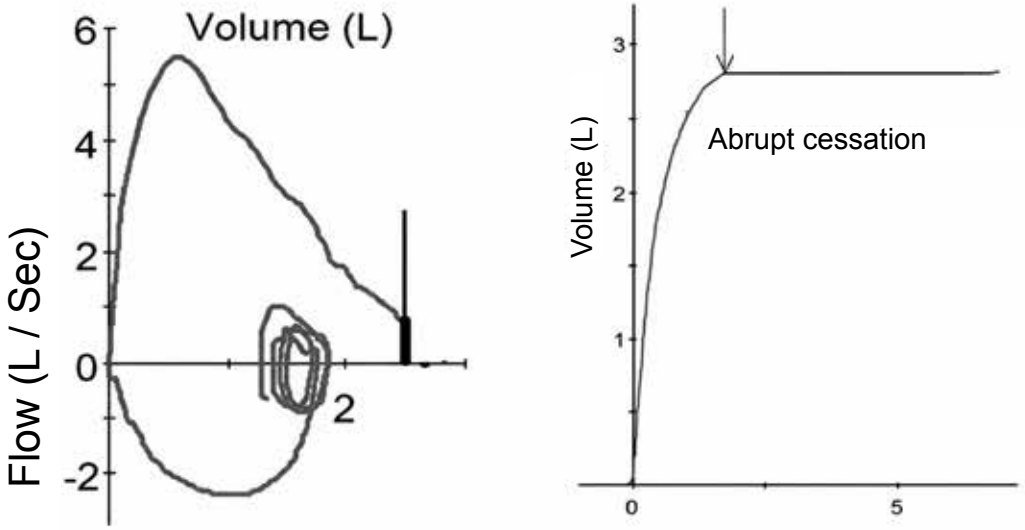


Figure 8: Premature termination
(Source: MTS-MOH Spirometry Certification Programme

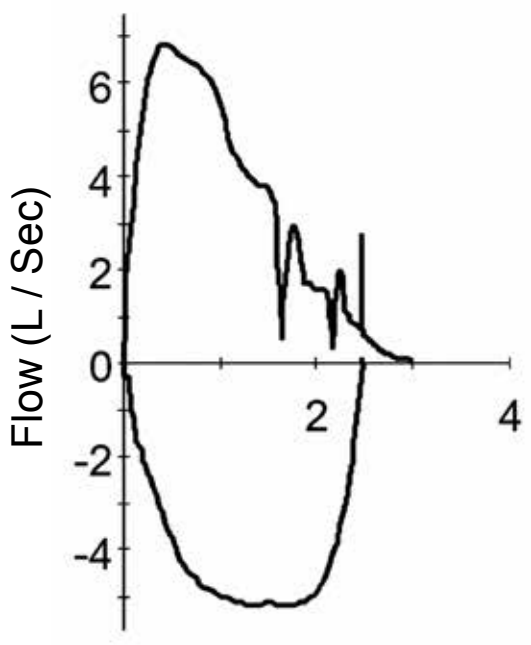


Figure 9: Coughs during the manoeuvre
(Source: MTS-MOH Spirometry Certification Programme)

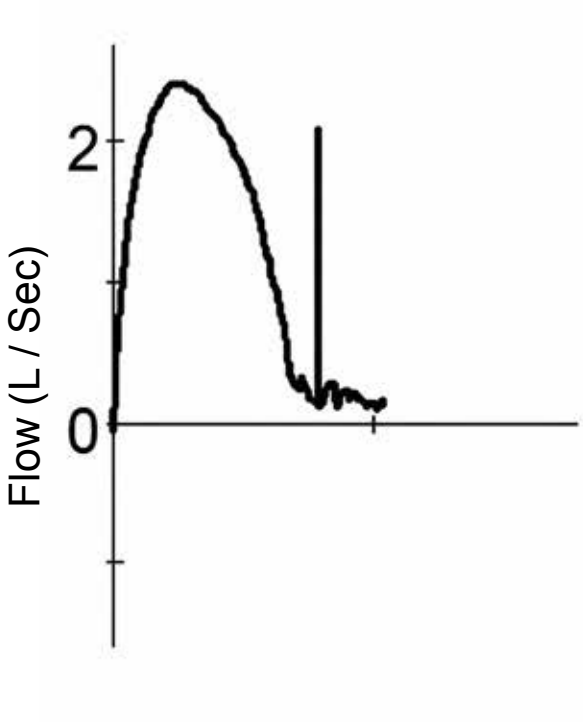


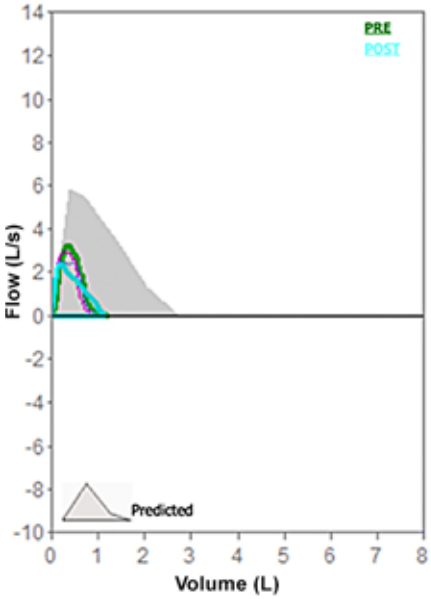
Figure 10: Obstructed mouthpiece
(Source: MTS-MOH Spirometry Certification Programme)

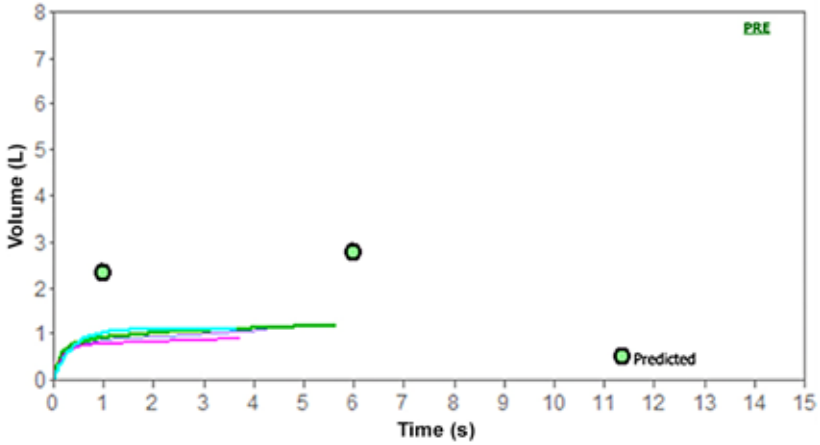
9.3 Case Illustrations

9.3.1 Case 1

A 49-year-old female factory operator undergoes spirometry as part of an occupational health assessment. She has worked in a manufacturing environment for approximately 20 years, with intermittent exposure to airborne dust and industrial particulates. She reports regular use of appropriate respiratory protective equipment. She is a lifelong non-smoker.

She presents with progressive exertional breathlessness and a non-productive cough for the past three months. She denies wheezing, chest tightness or previous history of asthma or chronic obstructive pulmonary disease. There is no known history of pulmonary tuberculosis or connective tissue disease. Physical examination is unremarkable.





PRE Trial 12:27:02 PM **POST Bronchodilation with salbutamol 12:49:58 PM**

Parameters	Unit	LLN	Pred	Best	%Pred	Z- score	PRE #1	PRE #2	PRE #3	POST	%Pred	% Chg
FVC	L	1.98	2.77	1.20	43	-3.26	1.20	1.07	0.9	1.19	43	-1
FEV,	L	1.66	2.30	0.96	42	-3.44	0.96	0.88	0.83	1.05	46	9
FEV,/FVC	%	71.2	82.8	80.0	97	-0.40	80.0	82.2	92.2	88.2	106	10

1. Quality Assessment

Acceptability

The start of the test assessed from the Flow–Volume curve demonstrates a rapid rise to peak expiratory flow without hesitation, indicating good initial effort. The end of the test assessed from the Volume–Time curve shows adequate expiratory effort with satisfactory completion of exhalation. There is no evidence of cough, glottic closure, air leak, or premature termination.

Therefore, the acceptability criteria are satisfied.

Repeatability

The two best FEV_1 values were 0.96 L and 0.88 L, with a difference of 80 mL, which is within the ATS/ERS acceptable limit of 150 mL.

The two best FVC values were 1.20 L and 1.07 L, with a difference of 130 mL, which is also within the ATS/ERS acceptable limit of 150 mL.

Therefore, the repeatability criteria are satisfied.

Spirometry is performed as part of the occupational respiratory evaluation.

2. Interpretation of Results

Assessment for Obstruction

Pre-bronchodilator FEV_1/FVC = 80.0%, which is above the LLN of 71.2%.

Therefore, there is no evidence of airflow obstruction from spirometry.

Assessment for Restriction

The FVC is 1.20 L (43% predicted), which is markedly reduced and below the LLN of 1.98 L.

This finding is suggestive of a severe restrictive ventilatory defect.

However, spirometry alone cannot confirm restriction. Confirmation requires measurement of static lung volumes, particularly Total Lung Capacity (TLC).

Bronchodilator Response (ERS/ATS 2022 Criteria)

Percentage change is calculated using the predicted value as the denominator:

FEV_1

Pre-bronchodilator FEV_1 = 0.96 L

Post-bronchodilator FEV_1 = 1.05 L

Predicted FEV_1 = 2.30 L

$$\frac{1.05-0.96}{2.30} \text{ X } 100\% = 3.9\%$$

A significant bronchodilator response requires an increase of ≥10% of the predicted value in either FEV_1 or FVC.

Therefore, there is no significant bronchodilator response according to the ERS/ATS 2022 criteria.

Final Conclusion

The findings demonstrate a severe restrictive ventilatory pattern/defect, characterised by a markedly reduced FVC with a preserved FEV_1/FVC ratio. There is no evidence of airflow obstruction and no significant bronchodilator response according to the ERS/ ATS 2022 bronchodilator responsiveness criteria.

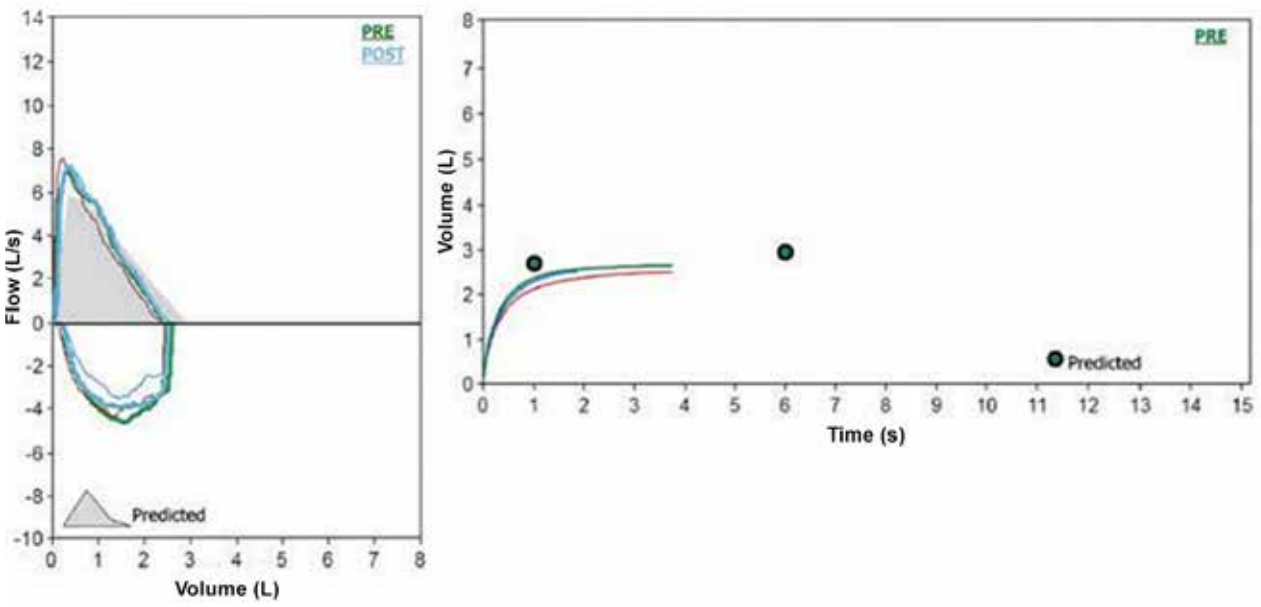
As spirometry test alone cannot confirm restrictive lung disease, and full pulmonary function testing including Total Lung Capacity (TLC) is recommended. Given the patient's respiratory symptoms and occupational dust exposure, further evaluation should be undertaken to exclude occupational interstitial lung disease, pneumoconiosis, or other causes of restrictive lung impairment.

9.3.2 Case 2

A 26-year-old male is applying for a job in an electronics assembly factory undergoes a pre-employment baseline spirometry. His job may involve exposure to soldering fumes and fine particulate matter; therefore, a baseline lung function test is required for surveillance.

He has no respiratory symptoms, denies cough, wheeze, chest tightness or exercise limitation. He is a non-smoker and has no history of asthma, tuberculosis or chronic lung disease.

Physical examination is normal with clear breath sounds bilaterally. Spirometry is performed.



PRE Trial 9:10:13 AM **POST Bronchodilation with salbutamol 9:32:59 AM**

Parameters	Unit	LLN	Pred	Best	%Pred	Z- score	PRE #1	PRE #2	PRE #3	POST	%Pred	% Chg
FVC	L	2.14	2.94	2.6	89	-O.70	2.60	2.49	2.45	2.58	88	-1
FEV,	L	1.96	2.6	2.36	91	-O.61	2.36	2.32	2.21	2.40	92	2
FEV,/FVC	%	78.6	90.3	90.8	101	-0.07	90.8	93.2	90.2	93.0	103	2

Integrated Spirometry Interpretation (Including Bronchodilator Responsiveness)

1. Quality Assessment

Acceptability

Start of test assessed on the Flow–Volume curve shows a sharp and rapid rise to peak expiratory flow, indicating good initial effort without hesitation. End of test assessed on the Volume–Time curve demonstrates adequate exhalation with a clear plateau, confirming reliable FVC measurement. No artefacts such as cough, early termination, glottic closure or air leak were observed. Therefore, acceptability criteria are satisfied.

Repeatability

The two best FEV_1 values were 2.36 L and 2.32 L, with a difference of 40 mL, which is within the acceptable limit of 150 mL.

The two best FVC were 2.60 L and 2.49 L, with a difference of 110 mL, which is within the acceptable limit of 150 mL.

Therefore, repeatability criteria are satisfied and the spirometry results are reliable.

2. Interpretation of Results

Assessment for Obstruction

FEV_1/FVC (2.36/2.6) ratio = 90.8% which is above the LLN 78.6%. Therefore, no airflow obstruction is present.

Assessment for Restriction

FVC is 2.60 L (89% predicted) which is above LLN 2.14 L, indicating normal lung volumes on spirometry. Therefore, there is no spirometry evidence of restriction.

Bronchodilator Response (New ERS/ATS Criteria)

Percentage change calculated using predicted value as denominator:

$(Post-Pre)/Predicted \times 100 = XXX$

Pre-bronchodilator FEV_1 = 2.36 L

Post-bronchodilator FEV_1 = 2.40 L

Predicted $FEV_1 \approx 2.6$ L

Bronchodilator response: $(2.40-2.36)/2.6 \times 100 = 1.5\%$

A significant bronchodilator response requires ≥10% of predicted value.

This result does not meet the threshold.

Therefore, there is no significant bronchodilator response.

Final Conclusion

This spirometry test meets acceptability and repeatability standards. The results demonstrate normal spirometry with normal FEV_1, FVC and FEV_1/FVC ratio. There is no evidence of obstructive or restrictive ventilatory defect and no significant bronchodilator response.

Overall, this represents normal spirometry test.

9.3.3 Case 3

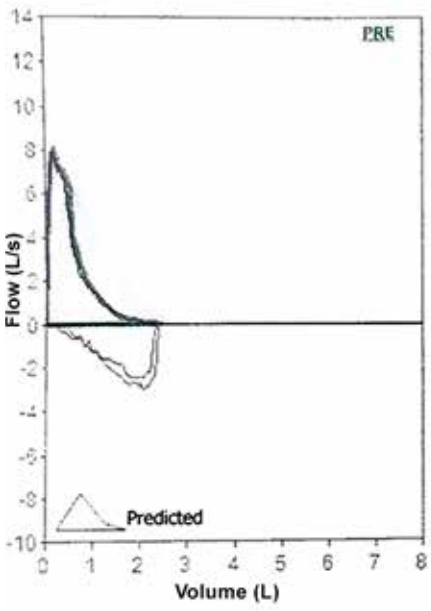
A 70-year-old male employee undergoing periodic occupational health surveillance presents for routine spirometry assessment.

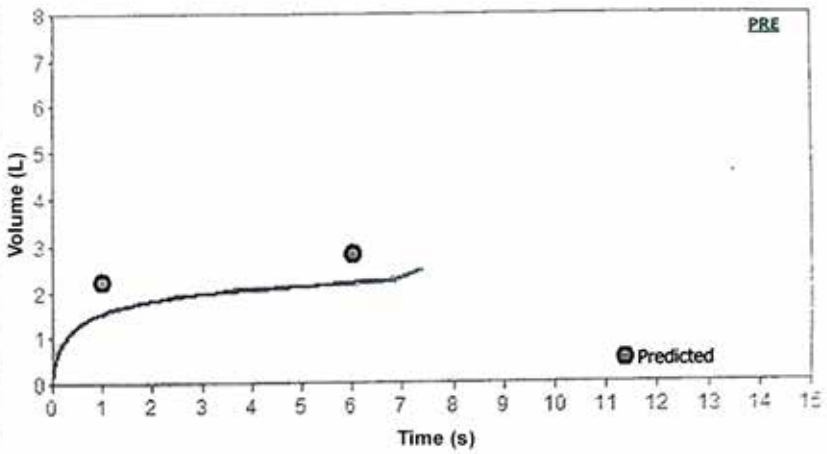
He has worked for 25 years in a light industrial setting with intermittent exposure to fumes and particulate matter.

He reports mild exertional breathlessness when climbing stairs but denies wheezing, chest tightness, or significant sputum production.

He has a smoking history of approximately 7 pack-years.

BMI is 20.2 kg/m² and there are no acute respiratory symptoms at the time of assessment.





PRE Trial 9:48:01 AM

Parameters	Unit	LLN	Pred	Best	%Pred	Z- score	PRE #1	PRE #2	PRE #3
FVC	L	1.75	2.81	2.46	88	-0.54	2.46	2.41	2.34
FEV,	L	1.35	2.21	1.61	1.61	-1.15	1.59	1.59	1.61
FEV,/FVC	%	70.4	80.6	65.4	65.4	-2.45	64.6	66.0	68.8

Integrated Spirometry Interpretation (Including Bronchodilator Responsiveness Test)

1. Quality Assessment

Acceptability

Start of test assessed on the Flow–Volume curve a rapid rise to peak flow, indicating adequate initial effort. The Volume–Time curve demonstrates satisfactory exhalation duration, suggesting adequate effort, although a full plateau is not clearly visualised on the report image. No cough, leak, or early termination is noted. Therefore, acceptability criteria are satisfied.

Repeatability

The two best FEV_1 values were 1.61 L and 1.59 L, with a difference of 20 mL, which is within the acceptable limit of 150 mL.

The two best FVC values were 2.46 L and 2.41 L, with a difference of 50 mL, which is also within the acceptable limit of 150 mL.

Therefore, repeatability criteria are satisfied, and the spirometry results are reliable

2. Interpretation of Results

Assessment for Obstruction

FEV_1/FVC (1.61/2.46) ratio = 65.4%, which is below the LLN 70.4%. Since FEV_1/FVC is below LLN, this indicates airflow obstruction.

Assessment for Restriction

FVC is 2.46 L (88% predicted) and above LLN 1.75 L, which is normal. Restriction is unlikely as FVC is not reduced.

Final Conclusion

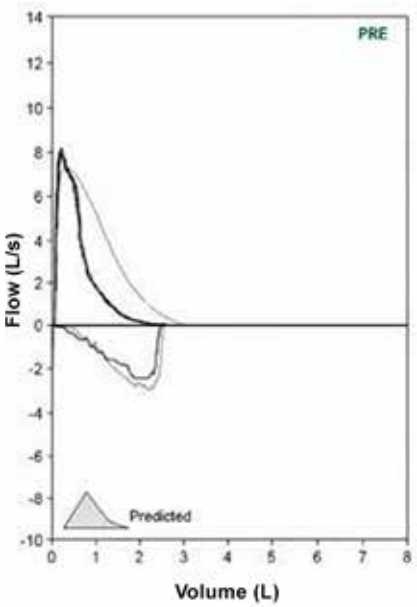
This spirometry meets acceptability and repeatability criteria. It demonstrated an obstructive ventilatory defect with preserved FVC and no spirometric evidence of restriction. Bronchodilator responsiveness test is recommended.

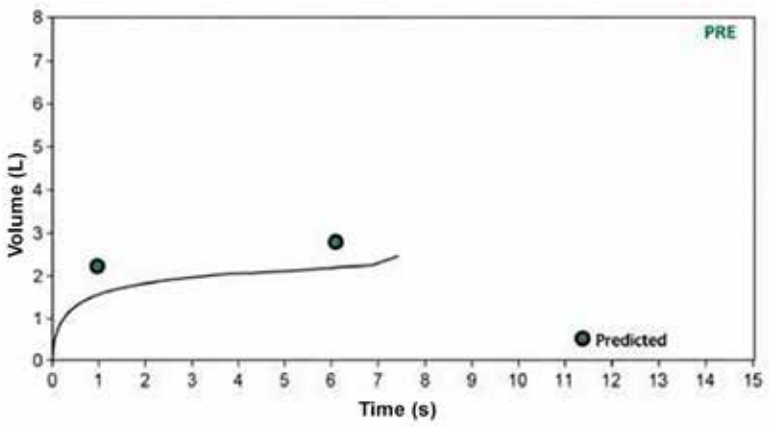
9.3.4 Case 4

A 40-year-old male maintenance technician working in a metal fabrication factory presents for periodic occupational health surveillance spirometry. He has been employed in the industry for 12 years, with intermittent exposure to metal fumes, welding smoke, and industrial dust despite the use of respiratory protective equipment.

He reports occasional shortness of breath when climbing stairs but no chronic cough, wheeze or history of asthma. He is a non-smoker and has no known chronic respiratory disease.

Physical examination is unremarkable. Spirometry is performed as part of routine occupational lung function surveillance.





Parameters	Unit	LLN	Pred	Best	%Pred	Z- score	PRE #1	PRE #2	PRE #3	POST	%Pred	% Chg
FVC	L	3.24	4.29	2.33	54	-3.07	2.33	2.17	2.26	2.55	59	9
FEV,	L	2.69	3.56	1.45	41	-4.02	1.45	1.40	1.31	1.64	46	13
FEV,/FVC	%	73.3	83.5	62.2	74	-3.44	62.2	64.5	58.0	64.3	77	3

Integrated Spirometry Interpretation (Including Bronchodilator Responsiveness)

1. Quality Assessment

Acceptability

Start of test assessed on the Flow–Volume curve shows a sharp and rapid rise to peak expiratory flow, indicating good initial effort without hesitation. End of test assessed on the Volume–Time curve demonstrates adequate exhalation with a plateau achieved, confirming reliable FVC measurement. No artefacts such as cough, early termination, glottic closure, or leak were observed. Therefore, acceptability criteria are satisfied.

Repeatability

The two best FEV_1 values were 1.45 L and 1.40 L, with a difference of 50 mL, which is within the acceptable limit of 150 mL.

The two best FVC values were 2.33 L and 2.26 L, with a difference of 70 mL, which is also within the acceptable limit of 150 mL.

Therefore, repeatability criteria are satisfied, and the spirometry results are reliable

2. Interpretation of Results

Assessment for Obstruction

FEV_1/FVC ratio (1.45/2.33) = 62.2%, which is below LLN 73.3%. Therefore, there is airflow obstruction.

Assessment for Restriction

FVC is 2.33 L (54% predicted) which is lower than LLN 3.24 L. A reduced FVC may indicate restrictive lung disease. However, spirometry alone cannot confirm restriction. Confirmation would require full lung volumes (TLC measurement).

Bronchodilator Response (New ERS/ATS Criteria)

Percentage change calculated using predicted value as denominator:

(Post − Pre) / Predicted × 100 = XXX

Pre-bronchodilator FEV_1 = 1.45 L.

Post-bronchodilator FEV_1 = 1.64 L.

Predicted FEV_1 ≈ 3.56 L.

Bronchodilator response: (1.64-1.45)/3.56 x 100= 5.3%

Significant bronchodilator response requires ≥10% of predicted value for FEV_1 or FVC. This case does not meet the 10% threshold; therefore, there is no significant bronchodilator response

Final Conclusion

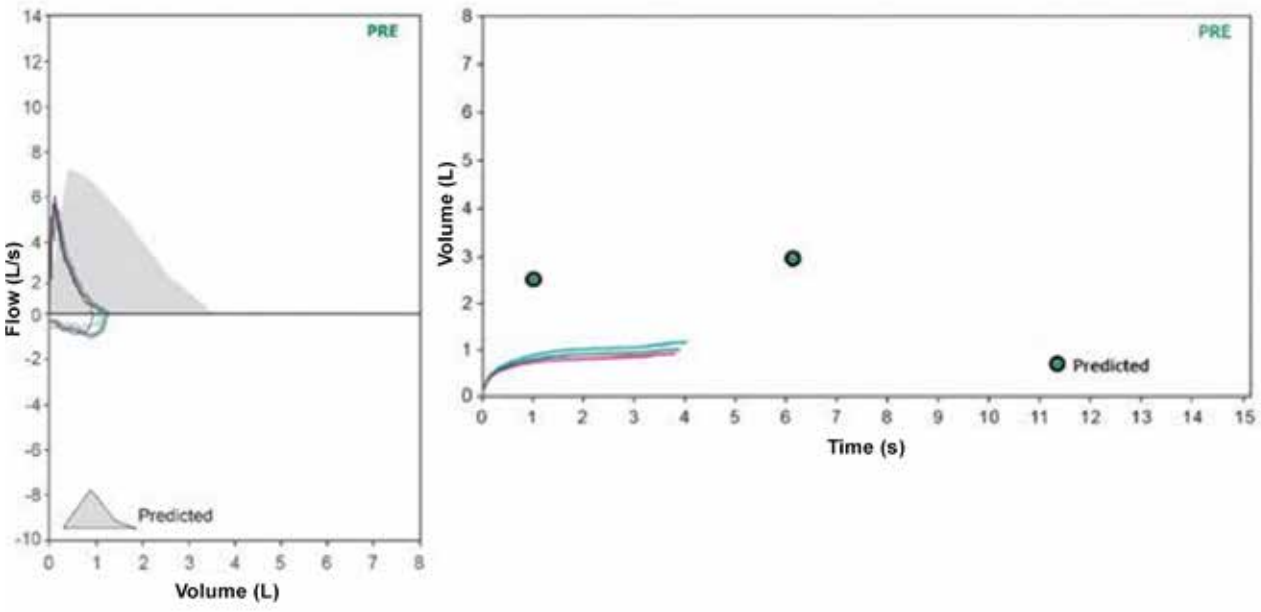
This spirometry meets acceptability and repeatability criteria. It demonstrates an obstructive ventilatory defect with possible restriction with no significant bronchodilator response. Further evaluation with full lung function test is recommended.

9.3.5 Case 5

A 50-year-old female administrative worker in a manufacturing company underwent periodic occupational health surveillance spirometry as part of routine workplace medical monitoring. She has worked in the company for 18 years, in office administration but also regularly visits production areas where she may be exposed to industrial dust and chemical fumes.

She reported progressive shortness of breath when climbing stairs over the past year but denied wheeze, chest tightness or chronic sputum production. She is a non-smoker and has no prior diagnosis of asthma or COPD.

On chest auscultation, breath sounds were slightly reduced bilaterally and crackles were present at the bases. Spirometry was performed as part of occupational health lung function surveillance.



PRE Trial 8:48:20 AM

Parameters	Unit	LLN	Pred	Best	%Pred	Z- score	PRE #1	PRE #2	PRE #3
FVC	L	2.2	3.02	1.03	34	-4.12	1.03	0.93	0.77
FEV,	L	1.86	2.51	0.85	34	-4.25	0.82	0.85	0.73
FEV,/FVC	%	71.2	82.5	82.5	100	-0.05	91.4	91.4	94.8

Integrated Spirometry Interpretation (Without Bronchodilator Responsiveness)

1. Quality Assessment

Acceptability

Acceptability Start of test on the Flow–Volume curve demonstrates a rapid rise to peak expiratory flow indicating good initial effort. The Volume–Time curve shows adequate expiratory effort with consistent exhalation across multiple trials. No artefacts such as cough, glottic closure, early termination or air leak are seen. Therefore, acceptability criteria are satisfied.

Repeatability

The two best FEV_1 values were 0.85 L and 0.82 L, with a difference of 30 mL, which is within the acceptable limit of 100 mL because the FEV_1 is less than 1.0 L.

The two best FVC values were 1.03 L and 0.93 L, with a difference of 100 mL, which is within the acceptable limit of 150 mL for FVC values greater than or equal to 1.0 L.

Therefore, the repeatability criteria are satisfied, and the spirometry results are reliable.

2. Interpretation of Results

Assessment for Obstruction

FEV_1/FVC (0.85/1.03) ratio = 82.5%, which is above the LLN 71.2%. Therefore, airflow obstruction is absent/ negative.

Assessment for Restriction

FVC is 1.03 L (34% predicted) which is lower than LLN 2.22 L. A reduced FVC may indicate restrictive lung disease. However, spirometry alone cannot confirm restriction. Confirmation would require full lung volumes (TLC measurement).

Final Conclusion

This spirometry meets acceptability and repeatability criteria. The results demonstrate a restrictive ventilatory pattern, characterised by normal FEV_1/FVC ratio (82.5%) and reduced FVC 1.03 L (LLN 1.86 L). These findings suggest restrictive lung disease. Confirmation with lung volume measurement is recommended.

10.0
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