National Asthma Council AUSTRALIA

The Spirometry Handbook for primary care

A guide to performing and interpreting spirometry for primary care health professionals

About this handbook

The spirometry handbook for primary care is intended as a guide for health professionals performing and interpreting spirometry in clinical practice, to ensure that high-quality testing is available and accessible for those with respiratory conditions.

It was developed by an expert working group of nurses, doctors and respiratory scientists convened by National Asthma Council Australia.

A quick reference guide accompanies this handbook (available at: www.nationalasthma.org.au)

Recommended citation

National Asthma Council Australia. The spirometry handbook for primary care. Melbourne; National Asthma Council Australia: March 2023.

A guide to performing and interpreting spirometry for primary care health professionals

Endorsed by the Thoracic Society of Australia and New Zealand

Contents

Introduction

Spirometry is an objective physiological test of lung function and is essential in the management of respiratory disease.

A spirometer measures how much, and how quickly, air can be exhaled in a single blow from full lungs. Some spirometers also measure airflow during inspiration. Results are available immediately.

Spirometry performance requirements[i] and testing methods are standardised.[1, 2] Lung function is assessed by comparing the individual's results with normal reference values and with previous results, if available.

Correct spirometry technique is crucial to obtaining reliable results for making a diagnosis or monitoring management of respiratory conditions. The test requires effort by the patient, so there must be cooperation between the operator and the patient, and continual coaching by the operator during the test.

With appropriate coaching, almost all adults and most children aged 6 years and older attending general practice can correctly perform the spirometry test.

The operator is responsible for determining which results are suitable for clinical interpretation. It is essential to meet acceptability and repeatability criteria for each test performed, before using the results to make clinical assessments.

The main purpose of this guide is to ensure that all patients with asthma or other respiratory conditions have access to high-quality spirometry.

Clinical roles of spirometry

Airflow during forced expiration is affected by the elastic recoil of lung tissue, resistance of upstream airways, and the strength of respiratory muscles. Expiratory flow can be reduced by narrowing of the airway lumen or thickening of the airway wall. Abnormal inspiratory flow (if measured) in the presence of otherwise normal spirometry is a feature of upper airway dysfunction, which requires specialist investigation.

Spirometry is used in the investigation of respiratory symptoms, in the diagnosis of respiratory conditions such as chronic obstructive pulmonary disease (COPD) and asthma (Table 1), in monitoring the treatment of respiratory diseases, in case-finding among asymptomatic patients (e.g. smokers at risk of COPD), in the assessment of preoperative risk, in monitoring lung health in workers occupationally exposed to respiratory irritants or allergens, in disability/impairment evaluations performed for occupational, recreational or insurance purposes, and in clinical and population research.

---

i   The 2019 joint official statement on the standardisation of spirometry by the American Thoracic Society (ATS) and European Respiratory Society (ERS)[2] introduced new requirements for the manufacture of spirometers. These performance standards apply to new spirometers, but are not met by all spirometers in use in Australia. During this transition, all spirometers used in clinical practice must meet the ATS/ERS 2005 standard[1] or the 2019 standard.[2]

Spirometric indices

Table 1. Recommendations for spirometry in national clinical guidelines for asthma and COPD

Asthma[3]

Any patient with suspected asthma

Making the diagnosis of asthma*

Confirming a past diagnosis

Assessing risk of flare-ups

Investigating recent worsening of asthma control

Monitoring response to a change in treatment

Periodically reviewing asthma (e.g. every 1–2 years)

At every visit for patients with severe asthma or patients with poor perception of airflow limitation (e.g. those who do not feel any different with a 15% decrease or increase in FEV_1)

COPD[4]

Investigation of:

— unexplained breathlessness

— cough that is chronic (daily for 2 months), intermittent, unusual

— frequent or unusual sputum production

— relapsing acute infective bronchitis

Case-finding in people exposed to tobacco smoke or occupational dusts and chemicals, or patients with a strong family history of COPD

Making the diagnosis of COPD†

Reviewing treatment response and disease progression in people with COPD

* Spirometric criteria in combination with clinical findings; the diagnosis of asthma cannot be made solely on the basis of spirometry findings, but also depends on clinical findings including symptoms and exclusion of alternative diagnoses.

† Spirometric assessment is essential to the diagnosis.

The key indices measured by a spirometer (Figure 1) are forced vital capacity (FVC), forced expiratory volume in 1 second (FEV_1), peak expiratory flow (PEF), and the ratio of FEV_1 to FVC (FEV_1/FVC ratio). If inspiratory airflow is assessed, forced inspiratory vital capacity (FIVC) is also measured (Table 2).

Figure 1. Idealised spirometry tracings from a healthy individual showing measurement of indices

Additional measures of lung function

Additional (including non-spirometric) measures of lung function are sometimes performed in lung function laboratories, if required in the further investigation of lung conditions.

These include residual volume (the volume remaining in the lung after a maximal exhalation), functional residual capacity (the volume of air present in the lungs at the end of passive expiration), total lung capacity (the maximum volume of air that can be contained in the lungs), and gas transfer (the ability to transfer gas from the lungs to the blood).

A. Normal volume–time curve (spirogram)
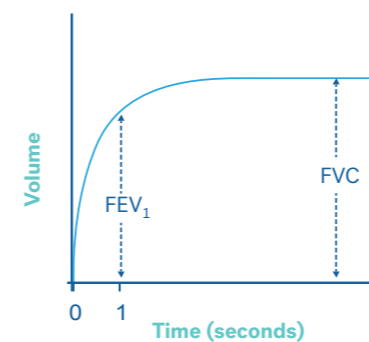
B. Normal flow–volume curve ('loop' if includes inspiratory curve)
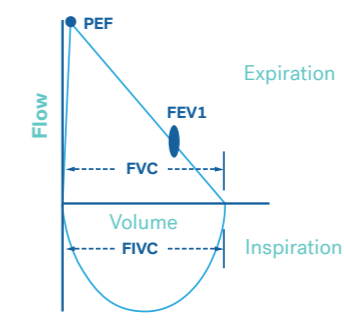
FEV1: forced expiratory volume in one second; FVC: forced vital capacity; FEF25%: forced expiratory flow at the point where 25% of FVC has been expired; FEF75%: forced expiratory flow at the point where 75% of FVC has been expired

Table 2. Spirometric indices

Abbreviation (units)	Name	Definition	Notes
Key indices			
FVC (litres)	Forced vital capacity	The maximum volume of air that can be expired during a single expiratory manoeuvre using maximal effort initiated following a full inspiration	Indicates lung capacity
FEV_1 (litres)	Forced expiratory volume in 1 second	The volume of air forcefully expired from full lungs during the first second of an expiratory manoeuvre	Indicates how quickly full lungs can be emptied, reflecting airway calibre
FEV_1/FVC (ratio)	Ratio of forced expiratory volume in 1 second to forced vital capacity	FEV_1 expressed as a fraction or percentage of FVC	Indicates whether expiratory airflow obstruction is present
PEF (litres/second or litres/minute)	Peak expiratory flow	The maximal expiratory flow achieved during the manoeuvre	Used for assessing effort Limited clinical application
FIVC (litres)	Forced inspiratory vital capacity	The maximum volume of air that can be inspired during a single inspiratory manoeuvre using maximal effort following a forced expiratory manoeuvre	Comparison of FIVC and FVC helps determine whether the patient began the forced expiration from full inflation

All volumes and flows are reported at body temperature and pressure saturated with water vapour (BTPS)

Spirometer specifications

Almost all spirometers currently used in Australia are flow spirometers. Flow spirometers use a sensor to measure flow and calculate volume electronically or digitally. The most commonly used sensors detect flow by measuring the pressure drop across resistance, electronically counting the rotation of a turbine blade, or by ultrasound.

The volume-displacement spirometer is an older type that is now rarely used in general practice. Volume-displacement spirometers usually provide a direct measure of respired volume from the displacement of a piston (rolling seal) or bellows (e.g. wedge bellows).

All spirometers used in clinical practice or research should meet performance criteria developed by the American Thoracic Society (ATS) and European Respiratory Society (ERS).[ii] These criteria were updated in 2019 (Table 3).[2]

Table 3. ATS/ERS spirometer performance criteria[2]

The current standard includes the following:

— The spirometry system meets International Organization for Standardization (ISO) Standard 26782.*

— Volume–time and flow–volume curves are displayed in real time.

— The volume–time curve shows exhalation from point of maximal inspiration or >1 second before time zero[#] (whichever occurs first), and up to either the end of the plateau or the beginning of next inspiration (depending on whether the inspiratory manoeuvre is being measured).

— Aspect ratio is 2:1 for printed volume–time curves.

---

* Exception: maximal permissible error of ± 2.5% for spirometer when volume accuracy tested with a 3-litre syringe, for which permissible error is ± 0.5%; total permissible error is ± 3.0%

See *Definition of start time*

[ii] Spirometers manufactured before introduction of the current standard[2] should meet the 2005 standard.[1]

Spirometry reference values

An individual's spirometry results are compared with reference values obtained from a well-defined population of normal subjects matched for sex, age, height and ethnic origin and using similar test protocols with carefully calibrated and validated instruments.[1]

The lower limit of normal (LLN) is usually defined as the cut-point for the bottom 5% of normal distribution (i.e. only 5% of the normal healthy population fall below this value). Comparison with LLN is useful for clinical interpretation.

An individual's results should also be compared over time with their 'personal best', because serial trends provide a better indication of change in lung function than predicted values.

Sex

When adjusted for height and age:[5]

— FEV_1, FVC, $FEF_{25-75\%}$ and PEF are higher in males than in females

— FEV_1/FVC ratio is slightly lower in males than in females.

Age

During adulthood there is a gradual fall in FEV_1, FVC, and PEF.[5]

FEV_1/FVC also decreases with age in adults, because FEV_1 declines more over time than FVC.[5]

Height

All indices except FEV_1/FVC increase with standing height.

Race/Ethnicity

Compared with Caucasians, FEV_1 and FVC values are lower in ethnic groups whose thorax is shorter relative to their height.[6] However, there is little difference in FEV_1/FVC ratio or PEF between ethnic groups.[5]

When adjusted for age and height:

— Caucasians are among the ethnic groups with the largest FEV_1 and FVC values[6]

— South-East Asians (including southern Indians), Sub-Saharan Africans and African-Americans have FEV_1 and FVC values lower than those of Caucasians[5, 6]

— Aboriginal and Torres Strait Islander people have FEV_1 and FVC values lower than those of Caucasians but higher than those of African-American people, based on findings in children and young adults aged 3–25 years.[7]

Choice of reference values

Multiple sets of reference values are available.

The Global Lung Initiative (GLI) 2012 reference dataset[5] is recommended for use in Australia and New Zealand.[8] It includes values for age ranges 3–95 years and for relevant ethnic groups.

The GLI-2012 category 'other/mixed' should be selected when performing spirometry for Aboriginal and/or Torres Strait Islander people.[7, 8]

NOTE: The use of reference values obtained from the third US National Health and Nutrition Examination Survey (NHANES III)[9] is no longer recommended.

Safety

Risks associated with the forced expiratory manoeuvre

Spirometry is generally safe. However, it requires maximal effort, which could result in transient breathlessness, cough, syncope, chest pain, oxygen desaturation or incontinence.

In patients with poorly controlled asthma, the forced manoeuvre can also induce bronchospasm. These people may show progressive decrease in FEV_1 with successive blows.

Spirometry should not be performed in patients at risk of complications due to high thoracic, abdominal, intracranial and intraocular pressures generated by the forced expiratory manoeuvre (Table 4).[2] When there is doubt about the safety of performing spirometry, the operator should consult the referring clinician or a specialist, as required.

People are unlikely to achieve optimal or repeatable results if they have:[10]

— an acute respiratory tract infection (e.g. cold or flu)

— chest or abdominal pain of any cause

— nausea

— diarrhoea

— oral or facial pain exacerbated by a mouthpiece

— stress incontinence

— dementia.

Table 4. Relative contraindications for spirometry[2]

Risk consideration	Condition(s)
Increase in myocardial demand or blood pressure	Acute myocardial infarction within 1 week
	Systemic hypotension or severe hypertension
	Significant atrial/ventricular arrhythmia
	Uncompensated heart failure
	Uncontrolled pulmonary hypertension
	Acute cor pulmonale
	Clinically unstable pulmonary embolism
	History of syncope related to forced expiration/cough
Increase in intracranial or intraocular pressure	Cerebral aneurysm
	Brain surgery within 4 weeks
	Recent concussion with continuing symptoms
	Eye surgery within 1 week
Increases in sinus and middle ear pressure	Sinus surgery within 1 week
	Middle ear surgery or infection within 1 week
Increase in intrathoracic and intra-abdominal pressure	Presence of pneumothorax
	Thoracic surgery within 4 weeks
	Abdominal surgery within 4 weeks
	Late-term pregnancy
Infection control	Active or suspected transmissible respiratory or systemic infection (e.g. tuberculosis)
	Conditions predisposing to transmission of infection (e.g. hemoptysis)
	Significant secretions
	Oral lesions or oral bleeding

Infection risk

Although few cases of infection transmission via spirometers have been documented, spirometry equipment has the potential to transmit pathogens through mouthpieces, valves and tubing, either through direct contact with bodily fluids or through droplet infection.[2]

Infection risk can be minimised by the routine use of infection control measures (Table 5). These include the use of disposable mouthpieces, mouthpiece valves and in-line filters, and cleaning and disinfection, in addition to general hygiene such as handwashing.

Disposable mouthpieces

Most spirometers use a single-use (disposable) sensor or mouthpiece.

Reusable mouthpieces must be cleaned, disinfected and dried after each patient. These are now rarely used and are not recommended.

Mouthpiece valves

Other devices use disposable mouthpieces containing a one-way valve to prevent inspiration through equipment. Only expiratory spirometry can be performed when these are used.

In-line filters

The usual way to prevent contamination of the interior surfaces of the spirometer is to use a disposable, low-resistance micro-aerosol filter inserted between the patient and spirometer. These in-line filters appear to be effective in reducing the risk of bacterial cross infection during inspiration,[11] but the use of filters does not eliminate the need for cleaning and disinfection.[10]

Cleaning and disinfection

Regardless of the filter or mouthpiece used, the spirometer should be cleaned and disinfected periodically (weekly or monthly) according to the manufacturer's instructions.

If disassembling the spirometer for cleaning, it is essential to:
— thoroughly dry the components before reassembling
— check the spirometer for correct operation
— recalibrate, if necessary.

Table 5. Summary of infection control measures

Handwashing between patients and after handling the spirometer
Single-use mouthpieces
Viral/bacterial filters
Single use spacers and MDI's
Following manufacturer's recommendations for cleaning and disinfection
Use of personal protective equipment (e.g. N95 masks, eyewear, gloves) as needed
Avoiding spirometry in patients with potentially transmissible diseases
Avoiding standing directly in front of coughing patient

Pre-appointment instructions for patients

General instructions

Patients should be advised to avoid:[2]

— smoking (including the use of electronic cigarettes or water pipe) for at least 1 hour before the test, to prevent acute bronchoconstriction

— consuming alcohol or other intoxicants for at least 8 hours before the test, to prevent problems with coordination, physical performance or comprehension

— exercising vigorously for at least 1 hour before the test, to prevent potential exercise-induced bronchoconstriction.

It is also helpful to advise patients to wear loose clothing that does not restrict the chest or abdomen[2] and empty their bladder before the testing session.

Patients who use a short-acting beta$_2$ agonist inhaler (e.g. those with asthma or COPD), should be asked to bring their own inhaler and spacer to use when testing bronchodilator responsiveness.

Withholding bronchodilators

When spirometry is performed as a diagnostic test, inhaled bronchodilators should be withheld before the test (Table 6). However, patients who use short-acting beta$_2$ agonists (e.g. for asthma or COPD) for symptom relief should still use these if needed.[3]

Patients who take regular long-acting beta$_2$ agonists in combination with inhaled corticosteroids for asthma should **not** be advised to withhold their medication before spirometry unless they are undergoing medically supervised withdrawal for the purpose of confirming the diagnosis.[3]

The operator should document whether the person has taken any bronchodilator on the day of spirometry, including the dose and time taken.

Table 6. Recommended minimal bronchodilator withholding times

Short-acting beta$_2$ agonists (SABAs) Salbutamol (e.g. *Asmol, Ventolin*) Terbutaline (e.g. *Bricanyl*)	4 hours
Short-acting muscarinic antagonists (SAMAs) Ipratropium (e.g. *Atrovent*)	12 hours
Long-acting beta$_2$ agonists (LABAs) **with twice-daily dosing** Formoterol (e.g. *DuoResp Spiromax, Flutiform, Oxis, Symbicort*) Salmeterol (e.g. *Fluticasone and salmeterol Cipla, Serevent, Seretide*)	24 hours
Long-acting beta$_2$ agonists (LABAs) **with once-daily dosing** Indacaterol (e.g. *Onbrez, Ultibro*) Olodaterol (e.g. *Spiolto*) Vilanterol (e.g. *Anoro, Breo, Trelegy*)	36 hours
Long-acting muscarinic antagonists (LAMAs) Aclidinium (e.g. *Bretaris, Brimica*) Glycopyrronium (e.g. *Seebri, Ultibro*) Tiotropium (e.g. *Braltus, Spiriva, Spiolto*) Umeclidinium (e.g. *Anoro, Incruse, Trelegy*)	

Withholding times apply when spirometry is performed as a diagnostic test (not for monitoring response to treatment). For combination therapies containing more than one listed medicine, use the longer withholding time.

Preparing the spirometer

Before a testing session, the spirometer should be prepared by following the manufacturer's instructions.

This includes determining the zero flow level for the spirometry system (with the spirometer blocked), if required for the device.

Setting up

The operator should check that the spirometer has been correctly set up and configured, which includes ensuring that the correct reference values have been selected and the LLN value calculation function has been enabled.

Calibration or an accuracy check (verification) should be performed.

A new disposable filter/mouthpiece must be attached for each patient.

Room temperature and pressure

Ideally, the spirometer should be allowed to acclimatise to the ambient conditions of the testing environment before use.

Some spirometers automatically measure and record ambient temperature and barometric pressure, while others require the operator to enter the data.

The flows and volumes measured at ambient conditions (i.e. the room temperature and barometric pressure on the day of the test) are converted to the flow and volume at the conditions within the lungs (i.e. body temperature and pressure saturated [BTPS] conditions). All electronic spirometers calculate and apply the BTPS correction factor automatically.

Patient data

The patient's information should be added:

— height[iii] without shoes (record to nearest 0.1cm)

— weight without shoes (record to nearest 0.5 kg)

— age (record birth date)

— biological sex at birth

— ethnicity/race (ask patient to identify)

— smoking status.

Height and weight should be measured every time before the test. The operator should not rely on data provided by the patient.[12]

If the patient has used an inhaled bronchodilator on the day of the test (or within the recommended withholding period), record the dose and time last taken.

Weight is not essential for obtaining the correct predicted values, but can be useful for interpretation.

Record the date of the session.

Preparing the patient to perform the test

Before starting the testing session, the operator should:

— explain to the patient that they will need to breathe in until they have completely filled their lungs, then blow out as hard and fast as they can into the mouthpiece until the lungs are completely empty. This could take a few seconds longer than feels comfortable.

— demonstrate the correct posture and the amount of force needed when exhaling.

— explain that this process will be repeated at least three times, and that several more attempts may be needed to get reliable results.

— advise the patient that doing the test properly (maximal effort) is hard work and they may become light-headed while blowing out, but they will be given a chance to rest between attempts. They should stop if they become excessively dizzy or if they have significant pain.

During the test, the operator should provide simple, clear instructions.

iii When measuring height the head should be in the Frankfurt Plane – eyes looking straight ahead and in line with the top of the ear.

Performing the test

The operator must wash their hands before and after the test, and wear gloves as needed.

Coaching and verbal encouragement during forced exhalation is essential to achieve maximal effort and complete exhalation.

The use of a nose clip is recommended for forced manoeuvres, but is not essential if only performing expiratory manoeuvres.

The sitting position is recommended to avoid falling due to syncope.[2] Reference values are derived from data obtained with spirometry from seated volunteers. The chair should have arms and not move on the floor.[2]

Upright posture is essential during the test.

**Closed-circuit method
(measuring expiratory and inspiratory flow)**

The patient should:

1. sit upright with their legs uncrossed and their feet flat on the floor, without leaning forward

2. place the mouthpiece in their mouth and close their lips to form a tight seal

3. breathe normally for 2–3 breaths

4. breathe in rapidly and deeply until their lungs are completely full

5. without pausing for more than 2 seconds, blast air out as hard and fast as possible and for as long as possible, until their lungs are completely empty or they cannot possibly blow out any longer[iv]

6. keeping a tight seal on the mouthpiece, breathe in again as forcefully and fully as possible

7. remove the mouthpiece and breathe normally.

**Open-circuit method
(measuring expiratory flow only)**

The patient should:

1. sit upright with their legs uncrossed and their feet flat on the floor, without leaning forward

2. breathe in rapidly and deeply until their lungs are completely full

3. immediately place the mouthpiece in their mouth and close their lips to form a tight seal

4. without pausing for more than 2 seconds, blast air out as hard and fast as possible and for as long as possible, until their lungs are completely empty or they cannot possibly blow out any longer.

5. remove the mouthpiece and breathe normally.

---

iv Under the ATS/ERS 2019 standard[2] the spirometry system must signal the operator when a plateau (flow <0.125 litres/min) has been reached or forced expiratory time reaches 15 seconds.

Acceptability and repeatability

Spirometry results are acceptable if the testing session yields manoeuvres (blows) that:

— meet objective criteria for determining that maximal effort was achieved and acceptable FEV_1 and/or FVC measurements were obtained (usually termed 'acceptability')

— meet criteria for consistency across multiple manoeuvres (usually termed 'repeatability').

However, occasionally FEV_1 or FVC measurements may be clinically usable even if they are not technically acceptable.[2]

Acceptability of a single manoeuvre (blow)

The patient must achieve both maximal inspiration and maximal expiration with a rapid start to the manoeuvre (blow).

The operator should visually inspect the performance of each manoeuvre to check if it meets acceptability criteria before proceeding with another manoeuvre.[2]

A manoeuvre is acceptable if:[2]

— it meets criteria for the start of forced expiration (see below)

— it meets criteria for the end of forced expiration criteria (see below)

— the operator observed that the patient achieved maximal inhalation and made maximal expiratory effort

— there is no evidence of other faults (see **Common faults**).

Definition of start time

The start time on the volume–time graph is defined by back-extrapolation from the steepest part of the volume–time curve. The line corresponding to this steepest section is extended below the curve (as though the tracing were linear, not curved). The point where this line crosses the time axis is the new time zero (Figure 2).[2] The back-extrapolated volume is the volume at the new time zero.

Most spirometers calculate these values automatically.

**Figure 2. Back-extrapolation to define the start time for expiration**
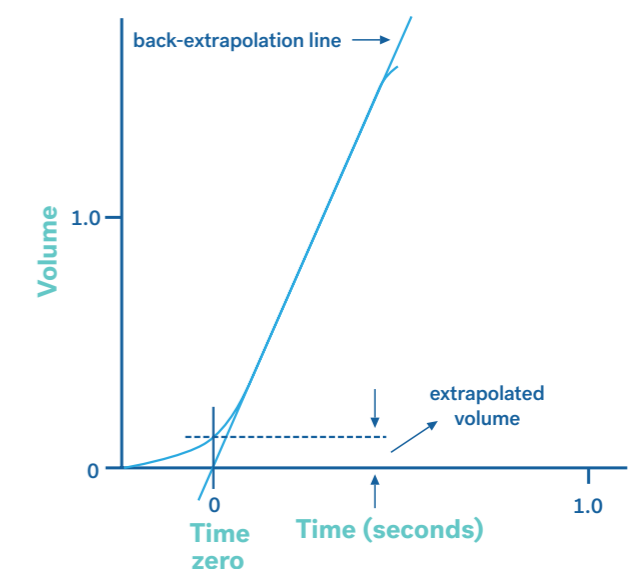
Criteria for start of forced expiration

The start of the test is acceptable if both of the following are achieved:

— the back-extrapolated volume is less than 5% of FVC or less than 0.100 L, whichever is greater

— the hesitation time is less than 2 seconds.

PEF should be achieved with a sharp rise and close to the start of expiration (time zero) on the displayed flow–volume curve (Figure 3).

Figure 3. Rapid versus poor start
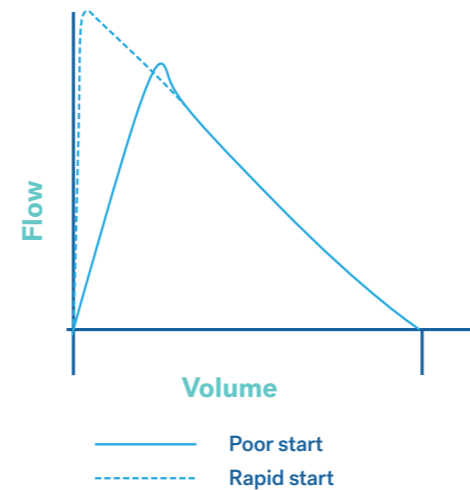
Strong effort by the patient is important for obtaining accurate values used in diagnosis and monitoring of respiratory diseases. In a person with obstructive lung disease, poor effort could lead to an overestimate of FEV_1 (Figure 4).

Figure 4. Flow–volume curve for patient with obstructive lung disease with poor effort

Submaximal effort

PEF   100 L/min
FEV_1 1.50 L

Maximal effort

PEF   150 L/min
FEV_1 0.90 L
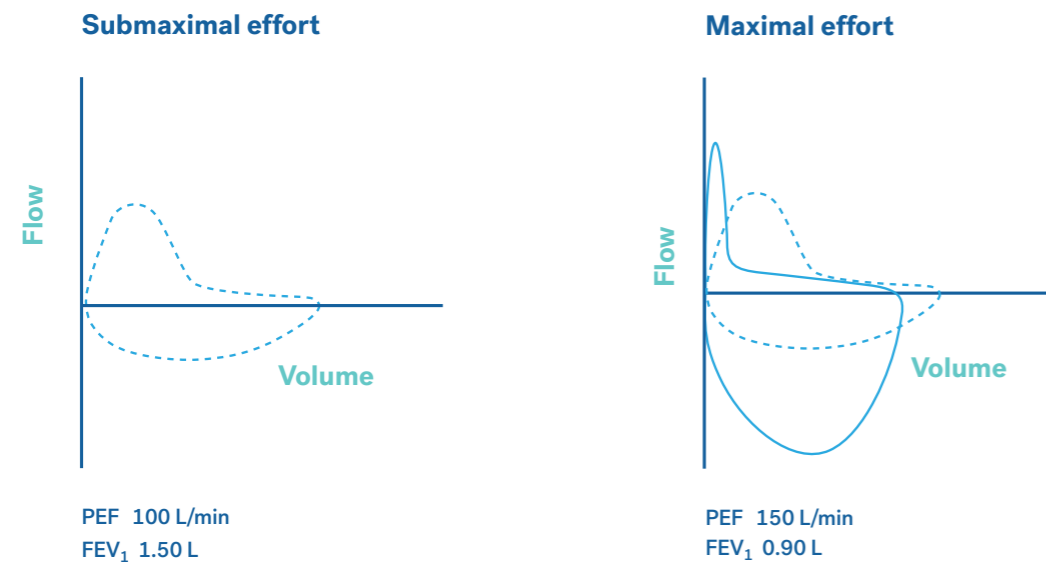
Tracings for same patient with submaximal and maximal effort, showing falsely elevated FEV_1 result with submaximal effort

Data provided by Eleonora (Nory) Del Colle

Criteria for end of forced expiration

The aim is to achieve smooth continuous exhalation with maximal effort until the lungs are 'empty'.

The end of the test is acceptable if **one** the following three criteria has been confirmed:[2]

1. The time–volume curve shows a definite plateau at the end, defined as no or minimal (<0.025 L) change in volume for at least 1 second.

OR

2. The patient has achieved a forced expiratory time (FET) of 15 seconds (i.e. has continued exhaling for 15 seconds), although a plateau has not been reached.

OR

3. The patient cannot expire long enough to achieve a plateau (as may occur in healthy children or in adults with restrictive lung disease), but FVC is greater than (or within repeatability limits of) their highest FVC value for the testing set (see *Repeatability of manoeuvres (blows)*, below).

Some spirometers record whether or not a plateau was achieved.[v]

The person should be encouraged to keep exhaling until one of these criteria has been achieved. However, they should be allowed to stop if they are experiencing excessive discomfort. The operator should also watch closely for signs of discomfort, and should stop the test if a patient is becoming significantly uncomfortable or appears to be at risk of syncope.[2]

Maximal inspiratory effort after the forced expiration

If the maximal inspiration (FIVC) is greater than forced expiration (FVC) by more than 0.100 L or 5% of FVC, this indicates that the patient did not start the test from full lung capacity.[2]

NOTE: Measurement of FIVC is not possible with spirometers that incorporate a one-way valve. Although the maximal forced inspiration manoeuvre is strongly recommended in the current international standard, it is not mandatory[vi] for judging a manoeuvre (blow) to be acceptable.[2]

Common faults

Common faults include:

— submaximal effort
— failure to fully inflate lungs before exhalation
— cough during the first second
— obstruction of mouthpiece by tongue or teeth
— air leak around mouthpiece
— extra breath during blow
— early termination
— glottic closure or vocalisation during exhalation.

These faults result in characteristic artefacts on the curves (Figure 5).

Submaximal efforts may be operator- or patient-related (Table 7) and are generally simple to eliminate.

---

v In accordance with the 2019 ATS/ERS standard,[2] newer spirometers provide an indicator when criteria 1 or 2 has been reached, both on the real-time display and via an audio alert, and signal if the manoeuvre fails criteria for end of forced expiration.

---

vi Inspiratory flow testing is essential when spirometry is performed specifically to investigate suspected extrathoracic obstruction[2]

Table 7. Causes of spirometry quality faults

Operator-related causes	Patient-related causes
Lack of tester knowledge/experience	Incomplete inhalation before starting forced exhalation
Inaccurately measured or entered patient details (i.e. age, sex, height and ethnicity)	Sluggish initial start to blow
Poorly maintained or calibrated spirometer	Premature termination of blow
	Tongue occlusion
	Biting the mouthpiece
	Glottic closure
	Cough – especially during the first second
	Vocalisation during the blow
	Poor posture (e.g. leaning forward too much)
	Leak (e.g. lips not sealed around mouthpiece)

Figure 5. Common patient-related faults
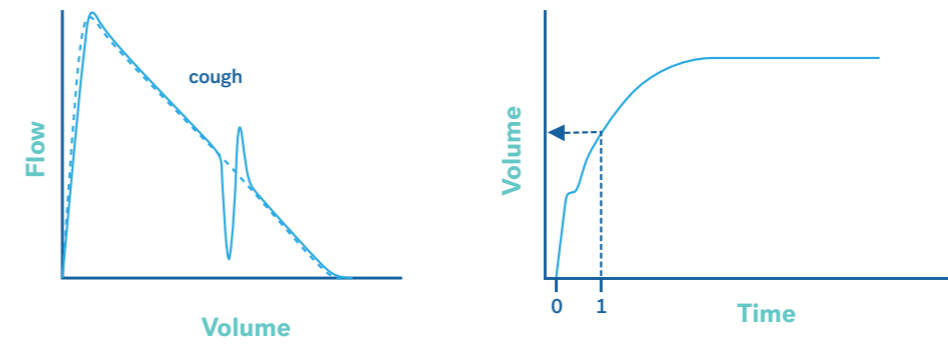
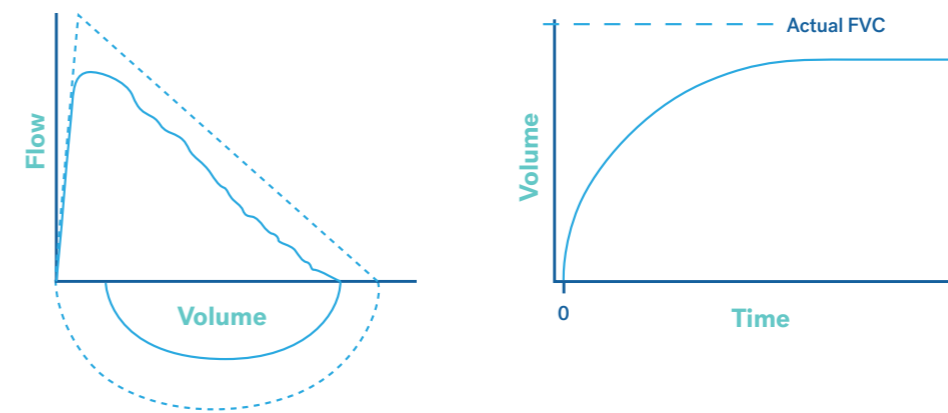**a. Variable and submaximal effort**
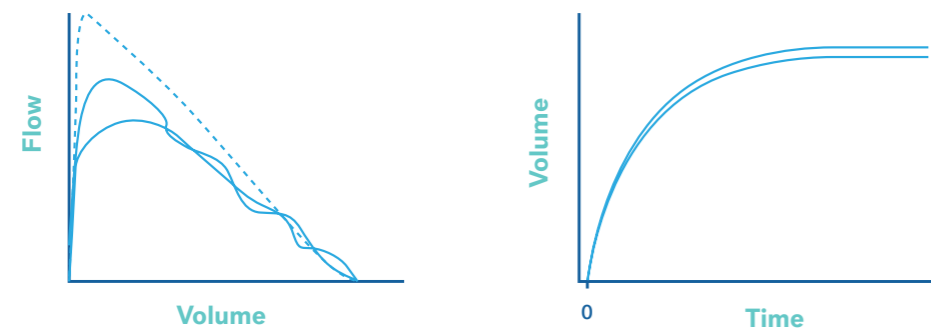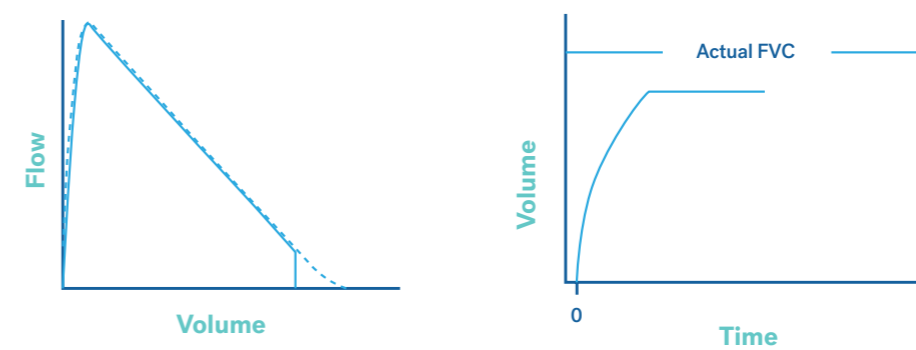

b. Poor start or hesitation
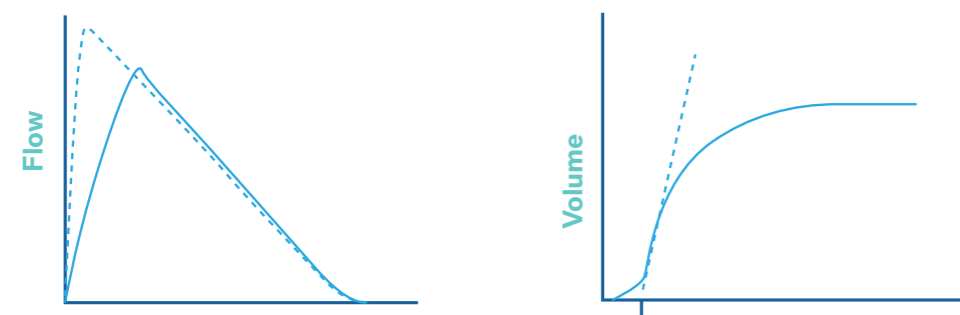
c. Cough before the first second of expiration

d. Submaximal inhalation before blow

e. Premature termination or glottic closure

Dotted lines in the flow–volume curves represent the expected tracing without the fault.

Repeatability of manoeuvres (blows)

Curves that meet both acceptability and repeatability criteria match closely when superimposed (Figure 6). Unacceptable efforts usually show variation in the shape of the curves and the values calculated.

Adults and children older than 6 years

FEV$_1$

The two largest values for FEV$_1$ from acceptable manoeuvres should be within 150 mL of each other.[2]

FVC

The two largest values for FVC from acceptable manoeuvres should be within 150 mL of each other.[2]

### Children aged 6 years or younger (if tested in primary care)

FEV$_1$

The two largest values for FEV$_1$ from acceptable manoeuvres should be within 100 mL or 10% of each other, whichever is greater.

FVC

The two largest values for FVC from acceptable manoeuvres should be within 100 mL or 10% of each other, whichever is greater.

Figure 6. Superimposed curves showing that repeatability criteria have been met
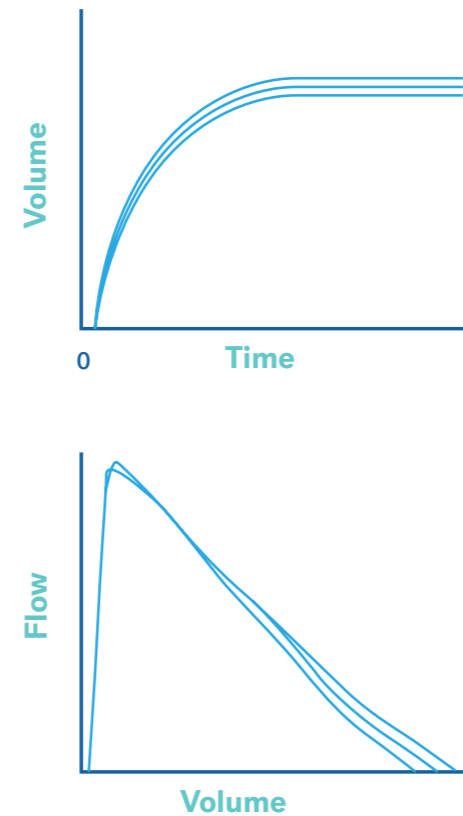
'Usable' data from unacceptable manoeuvres (blows)

Early termination, by itself, is not a reason to eliminate all the results from such a manoeuvre from further consideration.[2]

Manoeuvres that do not fully meet the acceptability criteria may still be usable (Table 8). For example:[2]

— FEV$_1$ may still be valid if cough or premature termination of the blow occurs after the first second.

— FVC may still be valid even though a plateau cannot be achieved at the end of a forced expiration, provided that the highest FVC values obtained within a set of manoeuvres are very similar.

The report should state when the results are obtained from manoeuvres that do not meet acceptability and repeatability criteria.

Table 8. Acceptable and usable results

Acceptable (7 conditions)	Conditions for acceptability of a single manoeuvre	Usable (2 conditions)
	1. At the start, no excessive hesitation or false start (extrapolated volume <5% of FVC or <0.100 L; whichever is greater)	
	2. No coughing or glottis closure during the first second* of the manoeuvre or that interferes with the measurement of accurate results in the operator's judgement	
	3. Meets criteria for end of forced expiration	May still provide usable FEV$_1$ or FVC value, but results should be interpreted with caution
	4. After the first second, no glottis closure or hesitation causing cessation of airflow	
	5. No leak around mouthpiece or in tubing	
	6. No obstruction of mouthpiece by tongue or teeth	
	7. No extra breath taken during exhalation	

* For children aged ≤6 years, must have at least 0.75 seconds of expiration without glottic closure or cough for acceptable or usable measurement of FEV$_{75\%}$
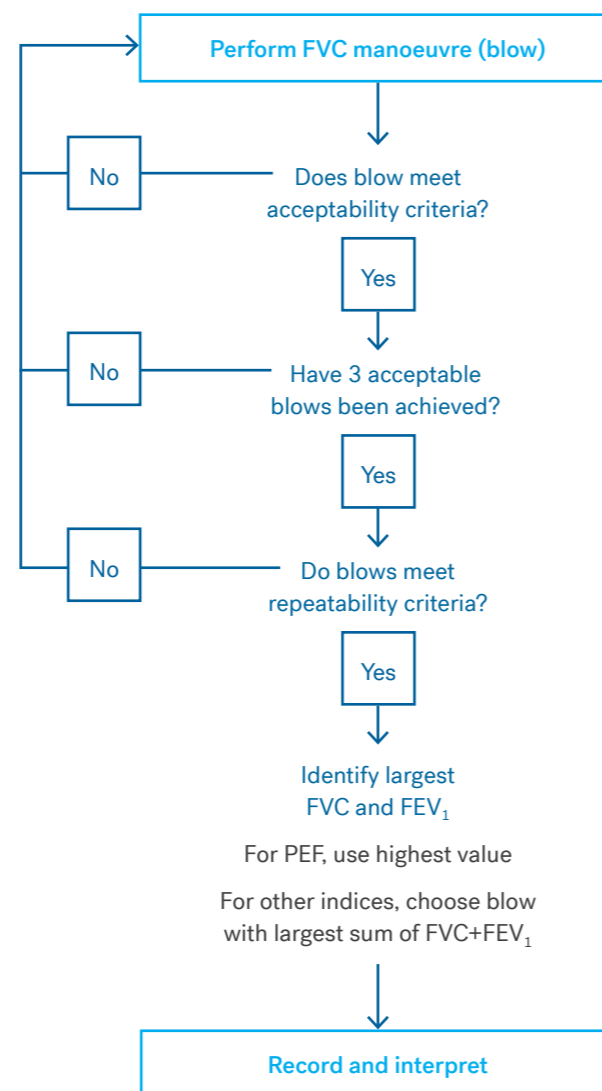
Completing the testing session

The test is complete when at least three manoeuvres (blows) have been obtained that meet acceptability and repeatability criteria.

The session should continue until either a complete test has been achieved, the patient has already made eight attempts, or the patient cannot continue.[2] Usually no more than eight blows in total should be attempted by an adult because the patient becomes exhausted and is unlikely to achieve better results.

If the spirometry session ended without fulfilling repeatability criteria, the operator should document the reasons. Inspection of the flow–volume curve will identify poor technique in most cases.

Figure 7. Decision process for completing a spirometry testing session

Perform FVC manoeuvre (blow)

No — Does blow meet acceptability criteria?

Yes

No — Have 3 acceptable blows been achieved?

Yes

No — Do blows meet repeatability criteria?

Yes

Identify largest FVC and FEV_1

For PEF, use highest value

For other indices, choose blow with largest sum of $FVC+FEV_1$

Record and interpret

Most spirometers will apply this algorithm automatically

Selecting results to record

Data should be recorded (Table 9) from at least three acceptable manoeuvres (blows) that meet repeatability criteria.

When acceptability and repeatability criteria are not met, FVC and FEV_1 should be measured from a series of at least three 'usable' blows[2] and the operator should note which conditions were not met.

FVC and FEV_1 can be taken from different curves – it is not necessary for them to have occurred in the same blow.[2]

NOTE: Newer spirometers automatically calculate the highest FEV_1 and FVC values from three acceptable blows. However, the operator is responsible for determining which results are suitable for clinical interpretation (Table 7). An operator can discern artefacts (e.g. biting on the mouthpiece) that would not be identified by the computer algorithm and could result in inaccurate flow rates. When an operator judges that a blow should not be used, it should be manually discarded.

Table 9. Spirometric indices to record from a testing session

FEV_1	The largest value from any acceptable blow
FVC	The largest value from any acceptable blow
FEV_1/FVC	Calculated from the largest acceptable FEV_1 and FVC
PEF	The largest value from any acceptable blow

FEV1: forced expiratory volume in 1 second; FVC: forced vital capacity; FEV1/FVC: ratio of FEV1 to forced vital capacity; PEF: peak expiratory flow

Assessing bronchodilator responsiveness testing ('reversibility')

Bronchodilator responsiveness (often called 'reversibility')[vii] is the extent to which expiratory airflow limitation is resolved by the administration of a rapid-acting bronchodilator. It is determined by performing spirometry before and after administering a short-acting beta$_2$ agonist, within the same session.

A spirometry test indicating a baseline result within normal limits may still demonstrate bronchodilator responsiveness.

Pre- and post-bronchodilator spirometry readings must be made and recorded at every spirometry test session in order to meet criteria for Medical Benefits Schedule reimbursement for spirometry testing (see Medicare items for office-based spirometry).

Facilities conducting bronchodilator responsiveness testing should have a written protocol for the test.[2]

Performing baseline and post-bronchodilator spirometry

1. A baseline complete spirometry test should be performed (meeting acceptability and repeatability criteria).

2. A bronchodilator dose is administered. A suggested protocol[viii] is four separate doses of salbutamol 100 micrograms/actuation administered via a pressurised metered-dose inhaler and spacer, waiting 30 seconds between each actuation.[1, 13]

3. The operator should wait 10–15 minutes. A minimum of 10 minutes is necessary to allow for maximal response.

4. A post-bronchodilator complete spirometry test should be performed.

The relative (percentage) and absolute changes in FEV$_1$ are calculated as follows:

$$FEV_1 \text{ \% response} = 100 \times \frac{FEV_1 \text{ (post bronchodilator)} - FEV_1 \text{ (baseline)}}{FEV_1 \text{ (baseline)}}$$

Absolute change in FEV$_1$ = $post\text{-}bronchodilator\ FEV_1 - baseline\ FEV_1$

Most spirometers automatically calculate percentage (but not absolute) change in FEV$_1$.

Definition of positive bronchodilator response

A positive bronchodilator response is defined according to clinically meaningful increases in FEV$_1$ and/or FVC.

The highest pre- and post-bronchodilator flow–volume curves can be displayed superimposed to provide a visual representation of the response (Figure 8).[14]

NEW STANDARD 2021 [19]
Adults and adolescents ≥12 years

A positive bronchodilator response is recorded if post-bronchodilator FEV$_1$ (and/or FVC) increases by at least 10% of predicted value.

OLD STANDARD
Adults and adolescents ≥12 years

A positive bronchodilator response is recorded if post-bronchodilator FEV$_1$ (or FVC) increases by at least 12% **and** the absolute increase in FEV$_1$ (or FVC) is at least 200 mL.

STANDARD UNCHANGED
Children up to 11 years

A positive bronchodilator response is recorded if post-bronchodilator FEV$_1$ (or FVC) increases by at least 12%.

Figure 8. Bronchodilator response
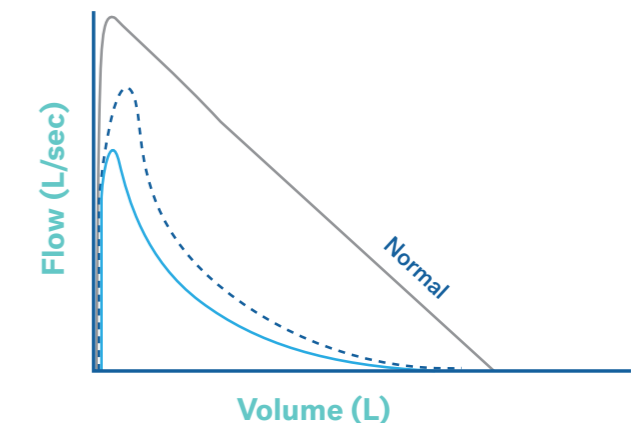
The highest pre-bronchodilator (solid line example) and post-bronchodilator (dotted line example) flow-volume curves superimposed in a patient with expiratory airflow limitation (obstructive pattern).

---

vii The 2019 ATS/ERS technical statement on the standardisation of spirometry[2] proposed that the term 'reversibility testing' should be replaced by the term 'responsiveness testing'. However, the term 'reversibility' is commonly used in practice.

viii For more information on protocols, refer to the online supplement for reference 2 (Section E9: Bronchodilator responsiveness testing protocol). For correct technique using metered-dose inhaler and spacer (single breath method), see National Asthma Council Australia. Inhaler technique for people with asthma or COPD. Melbourne: National Asthma Council Australia, 2018. Available at: https://assets.nationalasthma.org.au/resources/Inhaler-Technique-info-paper-20180607-web.pdf

Identifying abnormal ventilatory patterns

Spirometry results are interpreted by assessing the shape of the curves (particularly the flow–volume curve) and comparing the individual patient's values for spirometric indices with reference values obtained from populations matched for age, sex, height and ethnicity (see **Spirometry reference values**).

There are two main types of abnormal ventilatory patterns: obstructive and restrictive. Mixed patterns showing features of both are also possible.

Abnormal ventilatory patterns are assessed by comparison with cut-points based on LLN values (Table 10), as well as the shape of the flow–volume curve (Figure 9). In summary:

— FEV_1/FVC ratio is used to identify expiratory airflow obstruction.

— FEV_1% predicted is used to assess severity of expiratory airflow obstruction.

— FVC compared with LLN is used to identify potential restriction.

NOTE: Care should be taken in interpreting borderline values. An individual's spirometric values that approach LLN do not enable a diagnosis to be made with confidence, or a ventilatory defect to be ruled out.
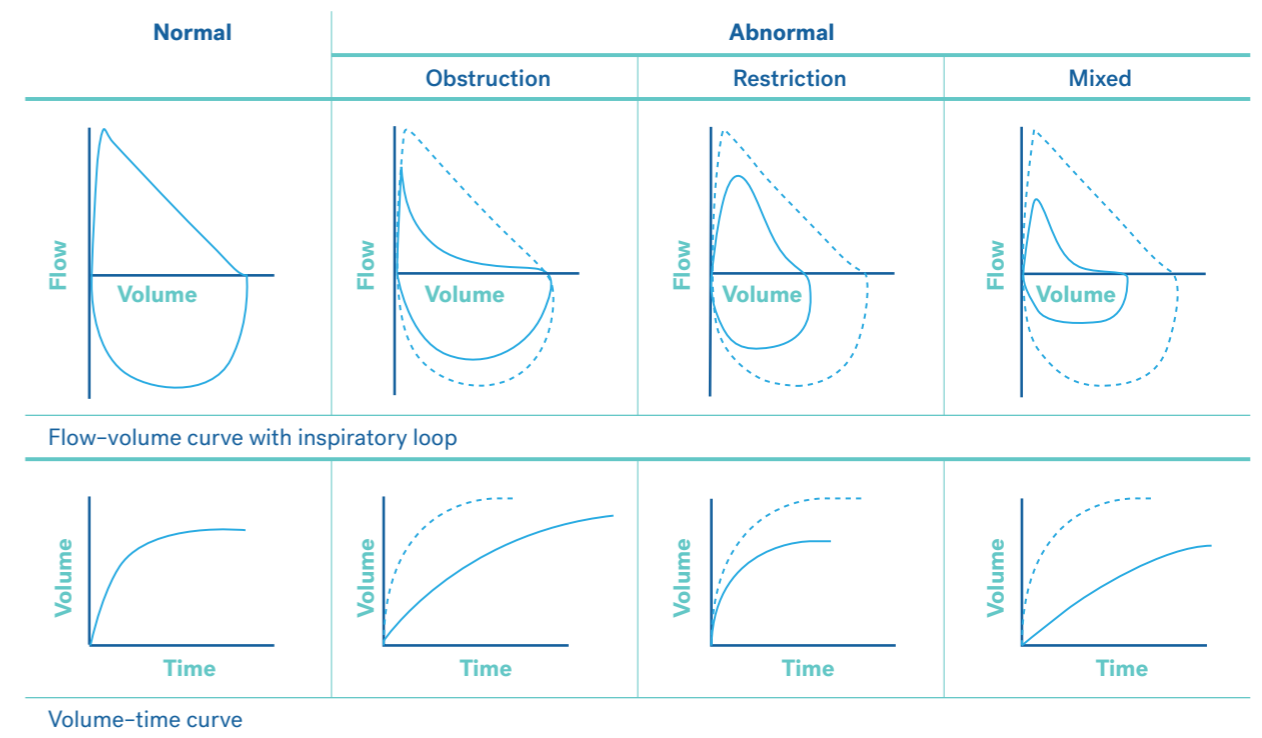
If LLN values are not available (e.g. with some older spirometers), fixed cut-points should not be used because these can over- or under-estimate results for younger and older age groups. For example, typical FEV_1/FVC values in healthy populations are highest in children and lowest in adults older than 60 years.[15] Online calculators are available for clinical and educational purposes.[ix]

Table 10. Definitions of abnormal ventilatory patterns

	Obstructive	Restrictive	Mixed
Pattern	Expiratory airflow limitation: unable to blow out quickly (e.g. asthma, COPD, asthma–COPD overlap)	Small lungs (e.g. pulmonary fibrosis, interstitial lung disease, pleural/chest wall disease, weak inspiratory muscles, rib deformity, obesity)	Small lungs and unable to blow out quickly (e.g. cystic fibrosis)
Spirometry findings	Low FEV_1/FVC (<LLN) Concave flow–volume curve	Low FVC (<LLN) FEV_1/FVC ratio normal or high Flow–volume curve shows small volume	Low FEV_1/FVC ratio (<LLN) Low FVC (<LLN) Reduced FEV_1 predicted Concave flow–volume curve with small volume

ix Online calculators are available at https://vitalograph.com/resources/gli-normal-values and https://www.ers-education.org/guidelines/global-lung-function-initiative/spirometry-tools/online-calculator.aspx

Figure 9. Recognising abnormal ventilatory patterns on spirometry curves

Flow–volume curve with inspiratory loop

Volume–time curve

Obstruction

Expiratory airflow obstruction means the person is unable to exhale quickly. Airflow obstruction implies that the airways are narrowed due to excess mucus, thickening of airway walls, inflammation, contraction of bronchial wall smooth muscle, or collapse of airways. This pattern can occur in asthma, chronic bronchitis, COPD, bronchiectasis, cystic fibrosis, or in patients with foreign bodies or tumours.[16] Apparent obstruction can be transient (e.g. when recorded during a severe acute infection of the respiratory tract).

An obstructive ventilatory pattern is characterised by:

— low FEV_1/FVC ratio (less than LLN)

— a concave flow–volume curve.

Care is needed in interpretation when FEV_1 and FVC are concomitantly decreased and the FEV_1/FVC ratio is normal or almost normal.[12] The most common reason for this finding is that the patient did not inhale or exhale completely.[12] However, it could also be seen in other situations:[12]

— when airflow is so slow that the subject cannot exhale long enough to empty their lungs to residual volume

— when patchy collapse of small airways occurs early in exhalation. Residual volume is likely to be increased in a patient with this condition.

When expiratory airflow obstruction is identified, FEV$_1$% predicted is used to classify severity.[12] The clinical significance depends on the individual's medical conditions and the context (e.g. the same value may have different clinical implications when measured in an emergency department to assess an acute exacerbation of asthma than when measured in the diagnostic investigation of suspected COPD).

Bronchodilator response is used to determine whether the person's expiratory airflow obstruction is responsive ('reversible') or non-responsive ('non-reversible') (Figures 10 and 11).

Responsive ('reversible') expiratory airflow obstruction is characteristic of asthma, where bronchospasm is relieved by rapid-acting bronchodilators. However, failure to demonstrate bronchodilator responsiveness does not exclude asthma, and its presence does not prove asthma – the pattern of symptoms and other clinical features must also be considered.[3]

Persistent ('fixed') airway narrowing is characteristic of COPD, where airways become permanently narrowed, even if some degree of bronchodilator response may be seen.

Figure 10. Obstructive patterns with and without bronchodilator response
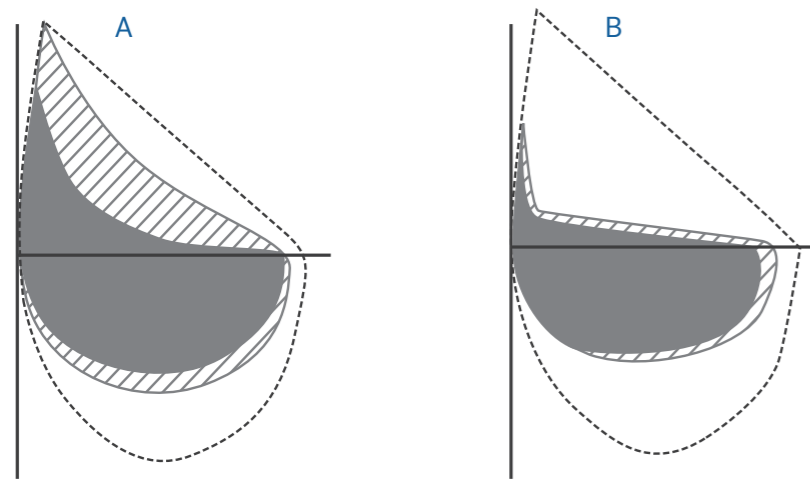
(A) Obstructive pattern with positive bronchodilator response ('reversibility')

(B) Obstructive pattern with minimal (clinically unimportant) bronchodilator response

Flow–volume loops for patients with obstructive patterns showing normal (predicted) curve (dotted line), pre-bronchodilator spirometry (shaded) and post-bronchodilator spirometry (striped).

Restriction

A restrictive ventilatory pattern reflects a small lung volume in the absence of airflow obstruction. It is characterised by:

— low FVC (less than LLN)

— FEV$_1$/FVC ratio normal or high

— a small volume seen on the flow–volume curve.

NOTE: Reduced FVC by itself does not prove true restriction.[12]

If a restrictive pattern is identified, further tests are needed to make a specific clinical diagnosis. Specialist referral for more complex lung volume measurement of total lung capacity is recommended.

True restriction means the person has reduced total lung capacity compared with normal. This can occur in people with pulmonary fibrosis, pulmonary oedema, interstitial lung disease, pleural/chest wall disease, weak respiratory muscles, rib deformity, neuromuscular diseases affecting respiratory muscles, pleural effusion or obesity.[16]

Mixed ventilatory pattern

A mixed pattern of both obstructive and restrictive features reflects reduced lung capacity in the presence of expiratory airflow obstruction (e.g. in a person with cystic fibrosis). It is characterised by:

— low FEV$_1$/FVC ratio (less than LLN)

— low FVC (less than LLN)

— reduced FEV$_1$% predicted

— a concave flow–volume curve with a small volume

Mixed ventilatory defects are relatively uncommon, compared with either an obstructive or restrictive pattern alone. This finding requires further assessment by a specialist respiratory facility.

Clinical interpretation of spirometry

Clinical decisions should not rely on numerical results without applying quality checks including checking the appearance of the curves.[12]

When making clinical assessments based on spirometry results, the clinician should take into account medications and the reasons for performing the test. For example, the absence of a positive bronchodilator response might be expected in a patient with asthma who is taking regular long-acting bronchodilators and is already maintaining their best possible lung function. This would represent a clinically desirable outcome if the spirometry test was conducted for the purpose of monitoring asthma, rather than as a diagnostic test.

If spirometry results are unexpected or difficult to interpret, the clinician should consider referral to a respiratory laboratory and/or respiratory physician.

For detailed clinical guidance on the interpretation of spirometry, clinicians should refer to current national guidelines on the diagnosis and management of respiratory diseases.

Figure 11. An approach to overall interpretation of spirometry results

Check shape of curve

FEV$_1$/FVC < LLN?

No → FVC < LLN? → No: Normal spirometry; Yes: Possible restriction

Yes → FVC < LLN? → No: Obstruction; Yes: Obstruction, possible mixed pattern

Positive bronchodilator response?
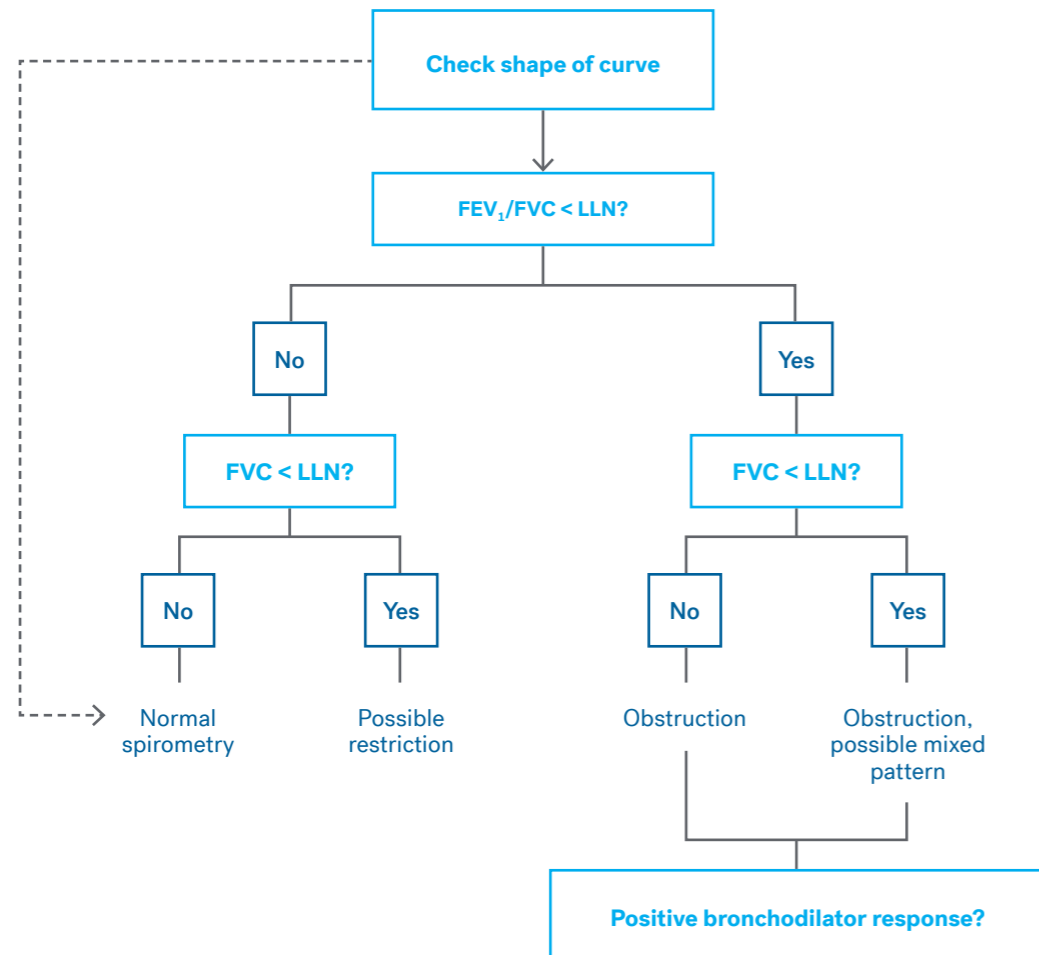
Severity grading of obstruction	Old standard FEV$_1$% predicted *	New standard using z scores
Mild	>70	-1.65 to -2.5
Moderate	60–69	-2.51 to -4.0
Moderately Severe	50–59	
Severe	35–49	< -4.1
Very Severe	<35	

Please note, the number and categories of cut-points are arbitrary.

Adapted with permission from Queensland Health Spirometry Training Program

Z - Score grading – for future use for interpretation

— A z score indicates how much a given value differs from the standard deviation

— Using z-scores is more consistent across age and sex than percent predicted

— Can be very useful in trending changes, especially in paediatric patients

— A z-score of < -1.65 means the result is below the lower limit of normal (LLN).

NOTE: Caution is required when interpreting results that fall close to LLN, especially when results are limited to a single test occasion.[17]

Quality assurance

Quality assurance procedures include:

— calibration checks according to the manufacturer's recommendations for the model of spirometer

— regular verification of calibration using a calibrated 3-litre syringe

— regular biological controls (spirometry performed on the same healthy adult)

— regular equipment maintenance

— infection control

— initial training and regular ongoing updates and refresher courses for operators.

Records of calibration checks, quality control and service history should be kept with the equipment.

Calibration and verification

Calibration determines the relationship between flow or volume measured by the spirometer and the actual flow or volume. Verification of calibration checks that the device is within standardised calibration limits.[2]

The frequency and processes for calibration checks depend on the type of spirometer (refer to manufacturer's operating manual).

ATS/ERS guidelines[2] recommend daily verification of calibration using a 3-litre syringe discharged at least three times to give a range of flows varying between 0.5 and 12 litres per second (with 3-litre injection times of 6 seconds and 0.5 seconds). The volume at each flow should meet the accuracy requirement of ±3.0%.[2x] The calibration syringe should be used under the same ambient conditions as the spirometer, so it should be allowed to reach the same room temperature before use. For devices using disposable flow sensors, a new sensor from the supply used for patient tests should be tested daily.

Refer to the manufacturer's instructions on interpreting verification of calibration, and what to do if the spirometry system fails a verification check.

The 3-litre syringe must also be checked regularly for accuracy, following the manufacturer's instructions. If dropped or damaged, the syringe should be checked for accuracy.

Biological controls

Comparison with a biological control is an additional method of checking spirometer accuracy over time. To establish a biological control, the spirometer is tested on a healthy control (a non-smoker free of known respiratory disease).

The person's normal range should be calculated as the average value obtained over at least 10 recordings. The same person's results should then be plotted over time. If the result falls outside the person's usual range, the spirometer should be checked for errors.

The biological control can be rechecked for comparison whenever a patient's results are suspected of inaccuracy.

A biological control is not a substitute for verification using a caliabration syringe, when a syringe is available.

x   Accuracy limits are ±2.5% for spirometry equipment and ±0.5% for calibration syringe (total ±3.0%)

Equipment maintenance

Operators should refer to the equipment manual for the manufacturer's recommended maintenance methods and schedule.

Operators should contact the supplier about notification of and access to software updates.

Ongoing maintenance generally includes:

— calibration check (or validation of accuracy)
— cleaning and disinfection procedures according to manufacturer's recommendations
— electrical operation and safety checks
— mechanical operation and safety checks
— software/database maintenance and back-up.

Record keeping

The log book for each spirometer should include records, including dates, of:

— calibration/verification results
— servicing
— mechanical or technical equipment problems and repairs
— software updates
— hardware changes.

Training for operators

Training and experience of the person taking the measurements is critical to the quality of the test and the reliability of results.

The quality of spirometry significantly improves with frequent performance by the operator. Spirometry must be conducted regularly to maintain competence. The TSANZ benchmark for maintaining competence among operators testing coal mine workers is 100 tests per operator per year.[14] TSANZ recommends that each operator keeps a log of tests performed.

Spirometry should only be performed by an operator who has completed a training course that meets TSANZ standards for spirometry training courses.[18]

Regular updating of knowledge and skills is essential especially, if spirometry is performed infrequently. TSANZ recommends that operators complete a refresher course 12 months after their initial training course, and then once every 3 years.[18]

Appendix

Medicare item numbers for office-based spirometry

Item 11505 – Measurement spirometry (diagnosis)

Service: Permanently recorded tracing, performed before and after inhalation of a bronchodilator – to confirm diagnosis of asthma, COPD or other causes of airflow limitation

Billing requirement: Each occasion at which 3 or more recordings are made. Applicable only once per patient in any 12-month period

Item 11506 – Measurement of spirometry (monitoring)

Service: Permanently recorded tracing, performed before and after inhalation of a bronchodilator – to confirm diagnosis of COPD, assess acute exacerbations of asthma, monitor asthma and COPD, assess other causes of obstructive lung disease or the presence of restrictive lung disease

Billing requirement: Each occasion at which recordings are made

More information

Graham BL, Steenbruggen I, Miller MR *et al*. Standardization of spirometry 2019 update. An official American Thoracic Society and European Respiratory Society technical statement. *Am J Respir Crit Care Med* 2019; 200: e70-e88.

NAC how-to video:
https://www.nationalasthma.org.au/living-with-asthma/how-to-videos/performing-spirometry-in-primary-care

Australian asthma handbook
(asthmahandbook.org.au)

The COPD-X plan
(available at https://copdx.org.au)

National Asthma Council Australia
(nationalasthma.org.au)

List of accredited respiratory laboratories maintained by TSANZ:
https://www.thoracic.org.au/respiratorylaboratoryaccreditation/australia

Abbreviations

ATS	American Thoracic Society
BTPS	Body temperature and pressure saturated with water vapour
COPD	Chronic obstructive pulmonary disease
ERS	European Respiratory Society
$FEF_{25-75\%}$	Forced expiratory flow between 25% and 75% of forced vital capacity
FET	Forced expiratory time
FEV_1	Forced expiratory volume in 1 second
FEV_1/FVC	Ratio of forced expiratory volume in 1 second to forced vital capacity
FIVC	Forced inspiratory vital capacity
FVC	Forced vital capacity
GLI	Global Lung Initiative
LLN	Lower limit of normal for demographic group
PEF	Peak expiratory flow
TSANZ	The Thoracic Society of Australia and New Zealand

References

1. Miller MR, Hankinson J, Brusasco V *et al.* Standardisation of spirometry. *Eur Respir J* 2005; 26: 319-38.

2. Graham BL, Steenbruggen I, Miller MR *et al.* Standardization of spirometry 2019 update. An official American Thoracic Society and European Respiratory Society technical statement. *Am J Respir Crit Care Med* 2019; 200: e70-e88.

3. National Asthma Council Australia. *Australian asthma handbook. Version 2.0.* Melbourne: National Asthma Council Australia; 2019.

4. Yang IA et al. The COPD-X Plan: Australian and New Zealand Guidelines for the management of Chronic Obstructive Pulmonary Disease 2020. Version 2.61 (February 2020). copdx.org.au

5. Quanjer PH, Stanojevic S, Cole TJ *et al.* Multi-ethnic reference values for spirometry for the 3-95 year age range: the global lung function 2012 equations. *Eur Respir J* 2012; 40: 1324-43.

6. Cotes J, Chinn D, MR M. *Lung Function: physiology, measurement and application in medicine.* 6th edn. Oxford: Blackwell Publishing Ltd; 2006.

7. Blake T, Chang A, Chatfield MD *et al.* Global Lung Function Initiative (GLI)-2012 'other/mixed' spirometry reference equation provides the best overall fit for Australian Aboriginal and/or Torres Strait Islander children and young adults. *Respirology* 2020; 25: 281-288.

8. Brazzale D, Hall G, Swanney MP. Reference values for spirometry and their use in test interpretation: a position statement from the Australian and New Zealand Society of Respiratory Science. *Respirology* 2016; 21: 1201-9.

9. Hankinson JL, Odencrantz JR, Fedan KB. Spirometric reference values from a sample of the general U.S. population. *Am J Respir Crit Care Med* 1999; 159: 179-87.

10. Miller MR, Crapo R, Hankinson J *et al.* General considerations for lung function testing. *Eur Respir J* 2005; 26: 153-61.

11. Bracci M, Strafella E, Croce N *et al.* Risk of bacterial cross infection associated with inspiration through flow-based spirometers. *Am J Infect Control* 2011; 39: 50-5.

12. Pellegrino R, Viegi G, Brusasco V *et al.* Interpretive strategies for lung function tests. *Eur Respir J* 2005; 26: 948-68.

13. Global Initiative for Chronic Obstructive Lung Disease. Spirometry for health care providers. 2016.

14. Thoracic Society of Australia and New Zealand. *Standards for the delivery of spirometry for coal mine workers.* Sydney: TSANZ; 2017.

15. National Heart Lung and Blood Institute National Asthma Education and Prevention Program. *Expert Panel Report 3: guidelines for the diagnosis and management of asthma. Full report 2007.* U.S. Department of Health and Human Services National Institutes of Health NHLBI; 2007.

16. Borg B, Thompson B, O'Hehir R. *Interpreting lung function tests: a step-by-step guide.* Chichester: Wiley-Blackwell; 2014.

17. Culver BH, Graham BL, Coates AL *et al.* Recommendations for a standardized pulmonary function report. An official American Thoracic Society Technical Statement. *Am J Respir Crit Care Med* 2017; 196: 1463-72.

18. Thoracic Society of Australia and New Zealand. *Standards for spirometry training courses. Companion document to Standards for the delivery of spirometry to spirometry for coal miners.* Sydney: TSANZ; 2017.

19. Stanojevic S, Kaminsky DA, Miller M, *et al.* ERS/ATS technical standard on interpretive strategies for routine lung function tests. *Eur Respir J* 2021;

20. Thoracic Society of Australia and New Zealand (TSANZ) and Australia and New Zealand Society of Respiratory Science (ANZSRS) August 2022

The Thoracic Society
of Australia & New Zealand
LEADERS IN LUNG HEALTH

DISCLAIMER
This handbook is not intended to be a comprehensive guide to spirometry. The National Asthma Council Australia expressly disclaims all responsibility (including for negligence) for any loss, damage or personal injury resulting from reliance on the information contained herein.

National
Asthma
Council AUSTRALIA

nationalasthma.org.au