# Standardised Operating Procedure

# Spirometry

## chILDRANZ 2020

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# Proposed Best Practice Checklist

## SPIROMETRY

### Diagnostic Indications

To evaluate symptoms, signs or abnormal laboratory tests. To measure the effect of disease on pulmonary function. To screen individuals at risk of having pulmonary disease. To assess pre-operative risk. To assess prognosis. To assess health status before beginning strenuous physical activity programmes.

### Monitoring Indications

To assess therapeutic intervention. To describe the course of diseases that affect lung function. To monitor people exposed to injurious agents. To monitor for adverse reactions to drugs with known pulmonary toxicity.

**Range and Accuracy Recommendations Specified for Forced Expiratory Manoeuvres**

| Test | Range/Accuracy (BTPS) | Flow range ($L \cdot s^{-1}$) | Time (s) | Resistance and back pressure | Test signal |
|---|---|---|---|---|---|
| **VC** | 0.5–8 L, ±3% of reading or ±0.050 L, whichever is greater | 0-14 | 30 | | 3-L Calibration syringe |
| **FVC** | | 0-14 | 15 | <1.5 $cmH_2O \cdot L^{-1} \cdot s^{-1}$ (0.15 $kPa \cdot L^{-1} \cdot s^{-1}$) | 24 ATS waveforms, 3-L Cal Syringe |
| **FEV1** | | 0-14 | 1 | <1.5 $cmH_2O \cdot L^{-1} \cdot s^{-1}$ (0.15 $kPa \cdot L^{-1} \cdot s^{-1}$) | 24 ATS waveforms |
| **Time zero** | The time point from which all $FEV_t$ measurements are taken | 0-14 | | Back extrapolation | |
| **PEF** | Accuracy: ±10% of reading or ±0.30 $L \cdot s^{-1}$ (20 $L \cdot min^{-1}$), whichever is greater; repeatability: ±5% of reading or ±0.15 $L \cdot s^{-1}$ (10 $L \cdot min^{-1}$), whichever is greater | 0-14 | | Mean resistance at 200, 400, 600 $L \cdot min^{-1}$ (3.3, 6.7, 10 $L \cdot s^{-1}$) must be <2.5 $cmH_2O \cdot L^{-1} \cdot s^{-1}$ (0.25$kPa \cdot L^{-1} \cdot s^{-1}$) | 26 ATS waveforms |
| **Instantaneous flows (except PEF)** | Accuracy: ±5% of reading or ±0.200 $L \cdot s^{-1}$, whichever is greater | 0-14 | | <1.5 $cmH_2O \cdot L^{-1} \cdot s$-1 (0.15$kPa \cdot L^{-1} \cdot s^{-1}$) | Data from manufacturers |
| **FEF 25-75%** | 7.0 $L \cdot s^{-1}$, ±5% of reading or ±0.200 $L \cdot s^{-1}$, whichever is greater | ±14 | 15 | Same as $FEV_1$ | 24 ATS waveforms |
| **MVV** | 250 $L \cdot min^{-1}$, at $V_T$ of 2 L within ±10% of reading or ±15 $L \cdot min^{-1}$, whichever is greater | ±14 (±3%) | 12-15 | <1.5 $cmH_2O \cdot L^{-1} \cdot s$-1 (0.15$kPa \cdot L^{-1} \cdot s^{-1}$) | Sine wave pump |

BTPS: body temperature and ambient pressure saturated with water vapour; VC: vital capacity; FVC: forced vital capacity; ATS: American Thoracic Society; FEV1: forced expiratory volume in one second; FEVt: forced expiratory volume in t seconds; PEF: peak expiratory flow; FEF25–75%: mean forced expiratory flow between 25% and 75% of FVC; MVV: maximum voluntary ventilation; VT: tidal volume.

## PROTOCOL FEV1 and FVC MANOEUVRE

FVC is the maximum volume of air exhaled with maximally forced effort from a maximal inspiration.

$FEV_1$ is the maximal volume of air exhaled in the first second of a forced expiration form a position of full inspiration.

There are three distinct phases to the FVC manoeuvre;

1) Maximal inspiration
2) A "blast" of exhalation, and
3) Continued complete exhalation to the end of test (EOT)

With appropriate coaching, children as young as 5 years of age are often able to perform acceptable spirometry [1].

### Equipment

The spirometer must be capable of accumulating volume for ≥15 s (longer times are recommended) and measuring volumes of ≥8 L (BTPS) with an accuracy of at least ±3% of reading or ±0.050 L, whichever is greater, with flows between 0 and 14 $L \cdot s^{-1}$. The total resistance to airflow at 14.0 $L \cdot s^{-1}$ must be <1.5 $cmH_2O \cdot L^{-1} \cdot s^{-1}$.

For the start of the test display, the volume-time display should include ≥0.25s, and preferable 1s before exhalation starts (zero volume).

The last 2s of the manoeuvre should be displayed to indicate a satisfactory end of test.

When a volume-time curve is plotted as hardcopy, the volume scale must be ≥10$mm \cdot L^{-1}$ (BTPS). For a screen display 5$mm \cdot L^{-1}$ is satisfactory.

**Recommended minimum scale factors for time, volume and flow on graphical output**

| Parameter | Instrument Display | | Hardcopy Graphical Output | |
|---|---|---|---|---|
| | Resolution Required | Scale Factor | Resolution Required | Scale Factor |
| Volume* | 0.050 L | 5 $mm \cdot L^{-1}$ | 0.025 L | 10 $mm \cdot L^{-1}$ |
| Flow* | 0.200 $L \cdot s^{-1}$ | 2.5mm $L^{-1} \cdot s^{-1}$ | 0.100 $L \cdot s^{-1}$ | 5mm $L^{-1} \cdot s^{-1}$ |
| Time | 0.2 s | 10$mm \cdot s^{-1}$ | 0.2 s | 20$mm \cdot s^{-1}$ |

*The correct aspect ratio for a flow versus volume display is two units of flow per one unit of volume

## $FEV_1$ and FVC TEST PROCEDURE

### Check the spirometer calibration

### Explain the test

### Prepare the subject

Ask about smoking, recent illness, medication use, etc.

Measure weight and height without shoes

### Wash hands

### Instruct and demonstrate the test to the subject, to include

Correct posture with head slightly elevated

Inhale rapidly and completely

Position of the mouthpiece (open circuit)

Exhale with maximal force

### Perform manoeuvre (closed circuit method)

Have subject assume the correct posture

Attach nose clip, place mouthpiece in mouth and close lips around the mouthpiece

Inhale completely and rapidly with a pause of <1 s at TLC

Exhale maximally until no more air can be expelled while maintaining an upright posture

Repeat instructions as necessary, coaching vigorously

Repeat for a minimum of three manoeuvres; no more than eight are usually required

Check test repeatability and perform more manoeuvres as necessary

### Perform manoeuvre (open circuit method)

Have subject assume the correct posture

Attach nose clip Inhale completely and rapidly with a pause of <1 s at TLC

Place mouthpiece in mouth and close lips around the mouthpiece

Exhale maximally until no more air can be expelled while maintaining an upright posture

Repeat instructions as necessary, coaching vigorously

Repeat for a minimum of three manoeuvres; no more than eight are usually required

Check test repeatability and perform more manoeuvres as necessary

## PROTOCOL CV and IC MANOEUVRE

The VC is the volume change at the mouth between the position of full inspiration and complete expiration. These manoeuvres are unforced, except at the point of reaching RV or TLC, respectively, where extra effort is required [2]. The slow VC can be derived in two ways:

- The expiratory vital capacity (EVC) is the maximal volume of air exhaled from the point of maximal inhalation.
- The IVC is the maximal volume of air inhaled from the point of maximal exhalation, achieved by a slow expiration from end-tidal inspiration.

The IC (inspiratory capacity) is volume change recorded at the mouth when taking a slow full inspiration with no hesitation, from a position of passive end-tidal expiration.

## VC TEST PROCEDURE - VC should be performed before FVC.

### Check the spirometer calibration

### Explain the test

Explain the subject must completely fill and empty their lungs

### Prepare the subject

Ask about smoking, recent illness, medication use, etc.

Measure weight and height without shoes

### Wash hands

### Instruct and demonstrate the test to the subject, to include

Correct posture with head slightly elevated

Position the nose piece

Position of the mouthpiece (open circuit)

Inhale completely: In a relaxed manner, except near end-inhalation

Exhale completely: with no force, except near end-expiration

### Perform manoeuvre (expiratory vital capacity EVC method) – where the subject exhales completely from a position of full expiration

Have subject assume the correct posture

Attach nose clip, place mouthpiece in mouth and close lips around the mouthpiece

*Exhale completely to RV*

*Inhale to TLC*

*Exhale to RV maximally until no more air can be expelled while maintaining an upright posture*

The subject should reach maximal inhaled an exhaled volume with a relatively constant flow

Repeat instructions as necessary, coaching vigorously

Repeat for a minimum of three manoeuvres; no more than eight are usually required

Check test repeatability and perform more manoeuvres as necessary

**Perform manoeuvre (IVC method) – where the subject inhales completely from a position of full expiration**

Have subject assume the correct posture

Attach nose clip, place mouthpiece in mouth and close lips around the mouthpiece

*Exhale completely to RV*

*Inhale to TLC*

*Exhale to RV maximally until no more air can be expelled while maintaining an upright posture*

The subject should reach maximal inhaled an exhaled volume with a relatively constant flow

Repeat instructions as necessary, coaching vigorously

Repeat for a minimum of three manoeuvres; no more than eight are usually required

Check test repeatability and perform more manoeuvres as necessary

## IC TEST PROCEDURE

### Check the spirometer calibration

### Explain the test

Explain the subject must completely fill and empty their lungs

### Prepare the subject

Ask about smoking, recent illness, medication use, etc.

Measure weight and height without shoes

### Wash hands

### Instruct and demonstrate the test to the subject, to include

Correct posture with head slightly elevated, with shoulders down and relaxed

Position the nose piece

Position of the mouthpiece (ensure no air leaks)

Breathe regularly for several breaths until the end-expiratory lung volume is stable (this usually requires at least 3 tidal manoeuvres)

Take one deep breath to TLC with no hesitation

### Perform manoeuvre

Have subject assume the correct posture

Attach nose clip, place mouthpiece in mouth and close lips around the mouthpiece

Breathe regularly for several breaths until the end-expiratory lung volume is stable (this usually requires at least 3 tidal manoeuvres)

Take one deep breath to TLC with no hesitation

Repeat instructions as necessary

Repeat for a minimum of three manoeuvres; no more than eight are usually required

Check test repeatability and perform more manoeuvres as necessary

## PEAK RESPIRATORY FLOW

PEF is the highest flow achieved from a maximum forced expiratory manoeuvre started without hesitation from a position of maximal lung inflation [3]. The defining characteristics of the flow–time curve, in relation to PEF, are the time taken for flow to rise from 10% of PEF to 90% of PEF, i.e. the rise time (RT), and the duration that flow is >90% of PEF, called the dwell time (DT).

## PEF TEST PROCEDURE

### Check the spirometer calibration

### Explain the test

Must be achieved as rapidly as possible and at as a high lung volume as possible

### Prepare the subject

Ask about smoking, recent illness, medication use, etc.

Measure weight and height without shoes

### Wash hands

### Instruct and demonstrate the test to the subject, to include

Correct posture with neck in neutral position, not flexed nor extended

Position of the mouthpiece (ensure no air leaks)

Inhale completely

Deliver a "blow" without hesitation

### Perform manoeuvre

Have subject assume the correct posture

The subject must not cough

Place mouthpiece in mouth

Inhale completely

Deliver a "blow" without hesitation

Repeat instructions as necessary

Repeat for a minimum of three manoeuvres; no more than eight are usually required

Check test repeatability and perform more manoeuvres as necessary

## MAXIMUM VOLUNTARY VENTILATION (MVV)

Largely superseded by $FEV_1$. The MVV is the maximum volume of air a subject can breathe over a specified period (12 s for normal subjects).

## MVV TEST PROCEDURE

### Check the spirometer calibration

### Explain the test

### Prepare the subject

Ask about smoking, recent illness, medication use, etc.

Measure weight and height without shoes

### Wash hands

### Instruct and demonstrate the test to the subject, to include

Correct seated posture

Position of the nose piece and mouthpiece (ensure no air leaks)

Perform 3 resting tidal breaths

Breathe as rapidly and deeply as possible

### Perform manoeuvre

Have subject assume the correct posture

Attach nose clip, place mouthpiece in mouth and close lips around the mouthpiece

Perform 3 resting tidal breaths

Breathe as rapidly and deeply as possible

Achieve ideal breathing rate of 90-110 breaths·min$^{-1}$

Repeat instructions as necessary

Repeat for a minimum of three manoeuvres; no more than eight are usually required

Check test repeatability and perform more manoeuvres as necessary

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