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Pulmonary function testing for the primary care nurse practitioner

Abstract: Knowledge of which pulmonary function tests are commonly performed in primary care and interpretation of their results is integral for the diagnosis, care, and management of those with pulmonary symptoms. This article provides an overview of the most common pulmonary function tests and interpretation of their results.

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In primary care, pulmonary function tests (PFTs) are used to provide supportive evidence to diagnose respiratory diseases, assess the progression of lung disease, monitor the impact of therapeutic interventions on lung function, and assess lung function prior to and after operative procedures.[1-4] Approximately 4% of all primary care visits are for respiratory complaints. PFTs, in conjunction with patient symptomology, serve as the foundation to distinguish between restrictive, obstructive, and mixed causes of lung disease.[1,3-5] Additionally, PFTs are used to monitor the progression and severity of lung diseases like asthma and chronic obstructive pulmonary disease (COPD).[1-4,6-9]

PFTs include the following: spirometry, peak expiratory flow, lung volumes, and diffusing lung capacity. Spirometry, which measures the volume of air moved and the movement of air in relation to time, is the most widely performed PFT in primary care settings, being considered the gold standard diagnostic test by national and international organizations to evaluate causes of airway obstruction and respiratory symptoms.[3-5] This article will review the most common primary care PFTs with a focus on spirometry by providing an overview of test procedures and interpretation of their results.

Spirometry indications

Spirometry is an effective means to evaluate dyspnea, gauge progression of chronic lung disease, and assess the impact of chronic disease progression. In preoperative patients with unexplained respiratory symptoms or chronic lung disease, spirometry can assist with surgical risk assessment and medical optimization.[4] Additionally, spirometry is useful in evaluating therapeutic interventions such as medication and inhaler use, monitoring of pulmonary complications related to pharmacologic therapies (such as amiodarone, methotrexate, and so on), and screening for pulmonary disease in patients with occupational exposures. Spirometry may also be used in workplace and disability assessments, rehabilitation programs, insurance assessments, and research studies.[4]

Spirometry contraindications

There are contraindications to the use of spirometry because it is an effort-driven assessment that generates an increase in

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thoracic pressure and myocardial demand by eliciting a cascade response that leads to an increase in blood, intracranial, and intraocular pressures.[3] The increase in thoracic pressure can subsequently increase intra-abdominal pressure, potentially adversely impacting both thoracic and abdominal organs. In 2019, formal guidelines were developed by the American Thoracic Society (ATS) and European Respiratory Society (ERS) that elaborated on spirometry contraindications.[3] Relative contraindications require evaluation of the risk of adverse events against the benefit of performing spirometry. Relative contraindications include conditions that may be impacted by increased intracranial, intra-abdominal, intrathoracic, or intraocular pressures, as well as infection control considerations (see *Relative contraindications for spirometry*).[3]

Relative contraindications for spirometry[3]

Due to increases in myocardial demand or changes in BP
- Acute myocardial infarction within 1 wk
- Systemic hypotension or severe hypertension
- Significant atrial/ventricular arrhythmia
- Noncompensated heart failure
- Uncontrolled pulmonary hypertension
- Acute cor pulmonale
- Clinically unstable pulmonary embolism
- History of syncope related to forced expiration/cough

Due to increases in intracranial/intraocular pressure
- Cerebral aneurysm
- Brain surgery within 4 wks
- Recent concussion with continuing symptoms
- Eye surgery within 1 wk

Due to increases in sinus and middle ear pressures
- Sinus surgery or middle ear surgery or infection within 1 wk

Due to increases in intrathoracic and intraabdominal pressure
- Presence of pneumothorax
- Thoracic surgery within 4 wks
- Abdominal surgery within 4 wks
- Late-term pregnancy

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

Spirometry should be discontinued if the patient experiences pain during the maneuver. Relative contraindications do not preclude spirometry but should be considered when ordering spirometry. The decision to conduct spirometry is determined by the ordering healthcare professional on the basis of their evaluation of the risks and benefits of spirometry for the particular patient. Potential contraindications should be included in the request form for spirometry.

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Spirometry testing

The National Asthma Education and Prevention Program, Global Initiative for Chronic Obstructive Lung Disease (GOLD), and the ATS and ERS guidelines recommend spirometry as an effective screening and diagnostic tool when combined with patient symptomology and history of disease presentation, noting that spirometry cannot be used as a standalone tool to diagnose lung disease.[3,6,9]

Clinical spirometry results are deemed reliable and accurate when certified, calibrated devices are used by skilled spirometry operators in adherence to the standard criteria for spirometry maneuvers with patients appropriately prepared.[3] Preparation of patients undergoing spirometry should consist of guidance on avoiding various activities and substances including, but not limited to, activities that could result in bronchoconstriction, fatigue, and/or impaired judgment. Use of consciousness- or mood-altering substances should be avoided for at least 8 hours, vaping or smoking for at least 1 hour, and participation in exhausting physical activities for at least 1 hour prior to testing.[3] For diagnostic testing, bronchodilators are held immediately prior to spirometry testing to allow for assessment of pulmonary responsiveness according to the following time frames: short-acting beta agonists (SABA) held 4 hours, short-acting muscarinic antagonists (SAMA) held 12 hours, long-acting beta agonists (LABA) held 24 hours, ultra-long-acting beta agonists held 36 hours, and long-acting muscarinic antagonists (LAMA) held 36 hours prior to testing.[4]

At the time of testing, the operator obtains and records the patient's age, gender at birth, ethnicity, weight, and height. Each of these variables impacts lung capacity and function; therefore, an accurate assessment of these indicators is important in providing predictive curves that are adjusted to the individual patient.[8] Further preparation includes ensuring the patient has an empty bladder and is seated. Proper coaching of the patient by the operator is critical to obtaining adequate, reproducible results. The operator provides clear instructions and demonstration of the required breathing maneuvers starting with the proper placement of the mouthpiece and occlusion of the patient's nose. Then patients are advised to perform deep inspiration and forceful continuous expiration, and this is followed by a deep inspiration if measures of total lung and inspiratory vital capacity are needed. To ensure validity of testing, the procedure should be repeated at least three times (maximum of eight attempts) for the best two acceptable attempts (sharp peak in the flow curve and expiration longer than 6 seconds) that are

reproducible (forced vital capacity [FVC] of the two readings within 0.15 L of each other).[8]

Spirometry interpretation

Spirometry measures the maximal volume of air moved in a single breath in relation to time.[3] Important spirometry measurements include the total volume of forced maximal expiration post maximal inhalation (or FVC); volume of air exhaled forcefully in the first second of expiration (forced expiratory volume in one second, FEV_1), and the fraction of FVC that can be exhaled in the first second, or FEV_1/FVC ratio. A stepwise systematic approach to interpreting spirometry assists the clinician in identifying obstructive, restrictive, and mixed airflow patterns associated with various pulmonary diagnoses (see *Interpretation and categorization of spirometry results*) and differential diagnoses of obstructive and restrictive lung diseases. Common differential diagnoses of obstructive lung disease include COPD, asthma, bronchiectasis, and cystic fibrosis.[10] Causes of restrictive lung disease include chest wall restrictions (ankylosing spondylitis, kyphosis, scoliosis, obesity), medications (amiodarone, methotrexate), interstitial lung disease, and neuromuscular disorders (myasthenia gravis, Guillain-Barré syndrome, muscular dystrophy).

Step 1: Assess FEV_1/FVC ratio for obstruction. The FEV_1/FVC ratio is most important in identifying airflow obstruction.[5] Obstructive airway diseases—such as COPD or asthma—are associated with a normal or decreased FVC, but reduced FEV_1, causing a reduced FEV_1/FVC ratio. The FEV_1/FVC value diagnostic of obstruction varies depending on the disease process and guideline. To elaborate, the FEV_1/FVC ratio is reduced in both COPD and asthma; however, it is typically higher in asthma than in COPD (see *Guideline comparison for FEV_1/FVC ratio criteria for obstructive lung disease*).[3,6,9] A normal FEV_1/FVC ratio is consistent with a normal or restrictive airflow pattern.

Step 2: Evaluate FVC for restriction. The FVC assesses the total volume of air with forced exhalation starting with lungs completely full.[5] A reduced FVC is most often associated with a restrictive pattern. A low FVC is defined as less than the lower limit of normal (LLN) or less than 80% predicted in adults or less than 80% of predicted in youth 5 to 18 years of age.[8,10] Suspected restrictive airway disorder requires referral for full pulmonary function testing in a lab, including lung volumes, the most accurate of which is body plethysmography.[4]

Step 3: Assess severity using FEV_1. FEV_1 assesses the volume of air exhaled in the first second of forceful exhalation and is an indicator of the severity of airflow limitation. FEV_1 is reported as a percentage of normal predicted value. Expiratory airflow limitation is associated with a reduced FEV_1. The lower the FEV_1 value, the greater the expiratory airflow limitation and severity of disease. In patients with an obstructive pattern consistent with COPD (decreased FEV_1/FVC ratio with normal FVC values) or mixed pattern (decreased FEV_1/FVC ratio and FVC values), the GOLD criteria can be utilized (see *Classification of airflow limitation severity in COPD: GOLD criteria*) to determine the severity of airflow limitation based on the FEV_1.[6]

For an obstructive pattern consistent with asthma (reduced FEV_1/FVC ratio and decreased FVC), the Global Initiative for Asthma (GINA) criteria can be utilized.[7] Patients with asthma with low FEV_1 percent predicted, especially if <60% predicted, indicates persons at risk for asthma exacerbations. Low FEV_1 percent predicted is also a risk factor for decline in pulmonary

Interpretation and categorization of spirometry results[4,8,10]

	Normal	Restrictive Pattern	Obstructive Pattern	Mixed Pattern
Interpretation	• FEV_1/FVC normal • FVC normal • FEV_1 normal	• FEV_1/FVC normal • FVC decreased • FEV_1 normal or slightly decreased	• FEV_1/FVC decreased • FVC normal or decreased • FEV_1 decreased	• FEV_1/FVC decreased • FVC decreased • FEV_1 decreased
5-18 years old	• FEV_1/FVC ≥ 85% • FVC ≥ 80% • FEV_1 > 80%	• FEV_1/FVC ≥ 85% • FVC < 80%	• FEV_1/FVC < 85% • FVC ≥ 80%	• FEV_1/FVC < 85% • FVC < 80%
>18 years old	• FEV_1/FVC ≥ LLN or > 70% • FVC ≥ LLN or > 80% • FEV_1 > 80%	• FEV_1/FVC ≥ LLN or > 70% • FVC < LLN or < 80%	• FEV_1/FVC < LLN or < 70% • FVC ≥ LLN • FEV_1 < 80%	• FEV_1/FVC < LLN or < 70% • FVC < LLN • FEV_1 < 80%

Abbreviations: FEV_1, forced expiratory volume in one second; FVC, forced vital capacity; LLN, lower limit of normal.

Note: Percentages listed are of predicted value.

Guideline comparison for FEV_1/FVC ratio criteria for obstructive lung disease[3,6,7,9,10]

GOLD	GINA	NAEPP guideline	ATS
<0.70	<0.75 in adults; <0.90 in children	<0.85 for patients 5-18 years of age	<LLN, defined as <5th percentile of spirometry data from NHANES III

Note: Table does not contain complete diagnostic criteria. Refer to guidelines for more information.

Abbreviations: ATS, American Thoracic Society; GINA, Global Initiative for Asthma; FEV_1, forced expiratory volume in one second; FVC, forced vital capacity; GOLD, Global Initiative for Chronic Obstructive Lung Disease; LLN, lower limit of normal; NAEPP, National Asthma Education and Prevention Program; NHANES III, Third National Health and Nutrition Examination Survey.

Classification of airflow limitation severity in COPD: GOLD criteria[6*]

GOLD 1	Mild	FEV_1 > 80% predicted
GOLD 2	Moderate	50% ≤ FEV_1 < 80% predicted
GOLD 3	Severe	30% ≤ FEV_1 < 50% predicted
GOLD 4	Very severe	FEV_1 < 30% predicted

*Based on postbronchodilator FEV_1.

Abbreviations: FEV_1, forced expiratory volume in one second; GOLD, Global Initiative for Chronic Obstructive Lung Disease.

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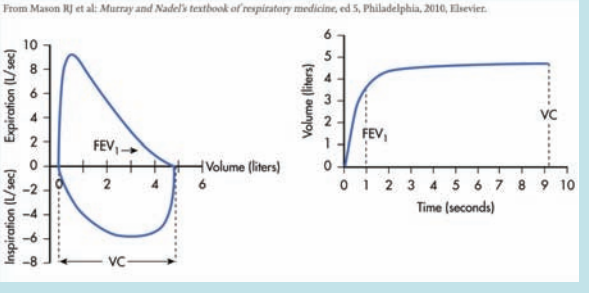
Example of normal spirometry results



FEV_1: forced expiratory volume in one second; VC: vital capacity

function.[7] High reversibility postbronchodilator in a patient taking controller or maintenance treatment can suggest uncontrolled asthma. For patients with an asthma diagnosis with numerous or repeated respiratory symptoms but nearly normal or normal FEV_1, alternative diagnoses must be considered, such as cough unrelated to asthma due to cardiovascular diagnoses, allergic rhinitis with postnasal drip, and so on.[7]

Step 4: Evaluate for reversibility with a bronchodilator. Airflow limitation characterized by an obstructive (decreased FEV_1/FVC ratio, decreased FEV_1), restrictive (normal FEV_1/FVC ratio, normal or slightly decreased FEV_1), or mixed (decreased FEV_1/FVC ratio, reduced FEV_1) pattern can be further evaluated for reversibility with a bronchodilator. For postbronchodilator reversibility evaluation, spirometry is performed followed by administration of a short-acting bronchodilator and repeat spirometry. FEV_1 reversibility is determined by the following calculation:

$$\%\ FEV_1\ \text{reversibility} = \frac{\text{Postbronchodilator } FEV_1 - \text{Prebronchodilator } FEV_1}{\text{Prebronchodilator } FEV_1} \times 100$$

Reversibility is most often associated with an obstructive pattern and the diagnosis of asthma. An increase in FEV_1 greater than 12% and 200 mL postbronchodilator is considered a positive bronchodilator reversibility test and, along with patient history, supports an asthma diagnosis.[7]

COPD is the likely diagnosis in adult patients with an obstructive pattern (decreased FEV_1/FVC ratio with normal or decreased FVC values) where there is *no reversibility*, and the FEV_1 remains less than 80% of predicted value, and the FEV_1/FVC ratio remains less than 0.7 after bronchodilator administration.[8]

In patients with a mixed pattern (decreased FEV_1/FVC ratio and FVC values), if the FVC improves significantly after bronchodilator administration, it is indicative of air trapping and likely COPD; if the FVC does not significantly improve after bronchodilator, the patient should be referred for full PFTs (see *Example of normal spirometry results*).[4,11]

Other PFTs common in primary care

Peak expiratory flow. Peak expiratory flow (PEF), another PFT, assesses the maximal rate that air can quickly be expelled from the lungs. PEF is commonly used in primary care for diagnosis or assessment of COPD and asthma. PEF is not the first-line diagnostic tool for COPD or asthma due to more reliable measures with spirometry. While PEF is sensitive for the diagnosis of COPD, it lacks specificity.[6] Due to PEF variability and its lack of correlation with spirometry, PEF should not be used as the sole method to diagnose COPD. However, in the absence of spirometry, PEF can be combined with validated self-assessment tools to provide supportive evidence for a diagnosis of COPD.[6] Spirometry is the gold-standard diagnostic tool for asthma; however, PEF may be used to determine reversibility and variability in symptoms to aid in asthma diagnosis when comparing the highest of three PEF readings pre- and postbronchodilator administration. It is important to use the same peak flow meter to ensure reliable measurements,

as results between meters can differ by as much as 20%.[7] Variability of greater than 10% in adults and 13% in children measured twice daily over 2 weeks is consistent with asthma diagnosis.[7] PEF is calculated during the effort-dependent portion of expiration and occurs during the first 200 ms. PEF can be impacted by numerous factors such as gender, age, height, muscle strength and effort, caliber of large airways, underlying medical conditions, and even the preceding inspiration. An estimated PEF can be calculated with the help of an online calculator.[12]

PEF is useful in self-monitoring and may be used to detect asthma changes including, but not limited to, exacerbations, worsening or improved symptoms, and response to chronic and rescue inhalers.[7] The accuracy of self-assessed PEF measurements depends on the employment of appropriate technique during testing and the administration of routine assessments, which helps one quickly determine the potential occurrence of an asthma exacerbation when results deviate from the patient's personal best. PEF values less than 80% of the patient's personal best warrant intervention from a provider. Furthermore, PEF values can be used to guide medical management and assess severity of asthma exacerbations.

Pulse oximetry. Pulse oximetry measures the percent of oxygen saturation in the blood. While not categorized as a PFT, this measurement is helpful in determining the need for oxygen therapy in patients with any respiratory symptoms or disease and should be used to assess all patients with clinical signs of respiratory failure or distress.[6] Pulse oximetry is easily incorporated into primary care and can help guide practitioners in their care of patients with common respiratory diagnoses, including asthma and COPD. In patients with COPD, a value of less than 92% would elicit an additional diagnostic test of blood gases to determine if supplemental oxygen is required; however, if oxygen saturation is less than 88%, patients should be started on supplemental oxygen with a saturation goal of 88% to 92%.[6] In patients with asthma, pulse oximetry is an important part of assessment of severity of exacerbations and determination of need for hospitalization.[13] In children or adults, oxygen saturation of less than 90% requires aggressive therapy including transfer to acute care facility.[7] Children with asthma presenting with a pulse oximetry measure of less than 92% (prior to oxygen or SABA administration) have high morbidity risk and likely require hospitalization.[7] Patients who are cyanotic or tachypneic or who receive emergent SABA, corticosteroid, and oxygen (if available) to manage an exacerbation but do not respond within 1 to 2 hours and/or their oxygen saturation remains lower than 94% on room air require hospitalization for observation and ongoing management.[7]

PFT results requiring referral

If spirometry results indicate a restrictive airway disease or if results are normal or deemed inconclusive in the presence of symptoms, patients should be referred to pulmonology for further testing.[10,14] Common PFTs utilized in pulmonology are lung volumes and diffusing capacity.

Lung volumes. Lung volumes consist of measurement of total lung capacity and other lung volumes, which are unable to be accurately assessed by spirometry.[4] The most accepted method for obtaining lung volumes is the employment of a whole-body plethysmography, which must be performed by a specialist and requires referral to pulmonology. In reference to the management of COPD or asthma, lung volumes are not supported as a required assessment tool by either set of guidelines; however, lung volumes can be used to assess disease severity in people with COPD.[6]

Diffusing capacity of the lungs for carbon monoxide. Diffusing capacity of the lungs for carbon monoxide (DLCO) is performed when postbronchodilator spirometry results do not discern between whether symptoms of shortness of breath, cough, dyspnea are related to asthma or COPD; however, it is not used in asthma management.[5] DLCO testing measures gas exchange, specifically exhaled amounts of helium and carbon monoxide.[5] Commonly, DLCO results are normal or mildly elevated in the case of asthma and reduced in COPD.[7]

When completing a pulmonary workup for COPD, the DLCO can be effective in providing additional information to support a diagnosis of COPD in patients with dyspnea that is not supported by spirometry results.

Discussion

PFTs are integral to the assessment, diagnosis, and management of pulmonary disease. Along with patient presentation, spirometry is the most sensitive and should be used in the diagnosis of patients presenting with respiratory symptoms.[6,7] For those diagnosed with asthma and COPD, spirometry should also be performed as part of the provider's follow-up assessment of prognosis and symptom control, and repeated at least annually for patients with COPD, and at least every 1 to 2 years for patients with asthma.[6,7] Findings from spirometry that indicate restrictive airway disease require referral for full

pulmonary function workup. Peak flow meters can also be helpful in primary care. They are used most often in asthma and are very helpful in self-management of symptoms when performed routinely with results documented. Pulse oximetry, while not classified as a PFT, is an important initial diagnostic and should be routinely used for all patients presenting in respiratory distress. Lung volumes and diffusing capacity tests are not typically available in primary care and require referral. Results from both tests can be used to determine disease severity and DLCO can be helpful in patients with COPD who present with breathlessness that appears to be out of proportion to their spirometry results.[6]

Although spirometry is recommended to be utilized and performed in primary care to correctly identify and diagnose lung disease early, the literature identified a gap in the estimated rates of actual primary care usage.[8] In offices that are not equipped with PFT equipment, specific tests can be ordered through local pulmonary/respiratory diagnostic labs or patients can be referred for evaluation and consultation with pulmonology.

Conclusion

PFTs act as guides to assist in the confirmation of diagnoses, measurement of disease severity, and determination of trends that indicate worsening of symptoms or exacerbations. As PFTs become more available in primary care, it is essential that providers familiarize themselves with the common tests, their uses, interpretation of results, and indications for referral for additional diagnostic tests.

REFERENCES

1. Tseng H-J, Henry TS, Veeraraghavan S, Mittal PK, Little BP. Pulmonary function tests for the radiologist. *Radiographics*. 2017;37(4):1037-1058. doi:10.1148/rg.2017160174.
2. Miller MR, Hankinson J, Brusasco V, et al. Standardisation of spirometry. *Eur Respir J*. 2005;26(2):319-338. doi:10.1183/09031936.05.00034805.
3. 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(8):e70-e88. doi:10.1164/rccm.201908-1590ST.
4. Langan RC, Goodbred AJ. Office spirometry: indications and interpretation. *Am Fam Physician*. 2020;101(6):362-368.
5. Dempsey TM, Scanlon PD. Pulmonary function tests for the generalist: a brief review. *Mayo Clin Proc*. 2018;93(6):763-771. doi:10.1016/j.mayocp.2018.04.009.
6. Halpin DM, Criner GJ, Papi A, et al. Global initiative for the diagnosis, management, and prevention of chronic obstructive lung disease. *Am J Respir Crit Care Med*. 2021;203(1):24-36.
7. GINA. Global Initiative for Asthma - Global Initiative for Asthma. 2021. www.ginasthma.org/.
8. GOLD Spirometry Guide - Global Initiative for Chronic Obstructive Lung Disease - GOLD. 2019. https://goldcopd.org/gold-spirometry-guide/.
9. Cloutier MM, Baptist AP, Blake KV, et al. 2020 Focused updates to the asthma management guidelines: a report from the National Asthma Education and Prevention Program Coordinating Committee Expert Panel Working Group. *J Allergy Clin Immunol*. 2020;146(6):1217-1270.
10. Johnson JD, Theurer WM. A stepwise approach to the interpretation of pulmonary function tests. *Am Fam Physician*. 2014;89(5):359-366.
11. Murray JF, Mason RJ. *Murray and Nadel's Textbook of Respiratory Medicine*. 5th ed. Philadelphia, PA: Saunders/Elsevier; 2010.
12. Estimated/expected peak expiratory flow (peak flow). MDCalc. www.mdcalc.com/estimated-expected-peak-expiratory-flow-peak-flow.
13. Hogan AD, Bernstein JA. GINA updated 2019: landmark changes recommended for asthma management. *Ann Allergy Asthma Immunol*. 2020;124(4):311-313.
14. Martinez-Pitre PJ, Bhanusivakumar SR, Cascella M. Restrictive lung disease. StatPearls [Internet]. 2021. www.ncbi.nlm.nih.gov/books/NBK560880/.

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