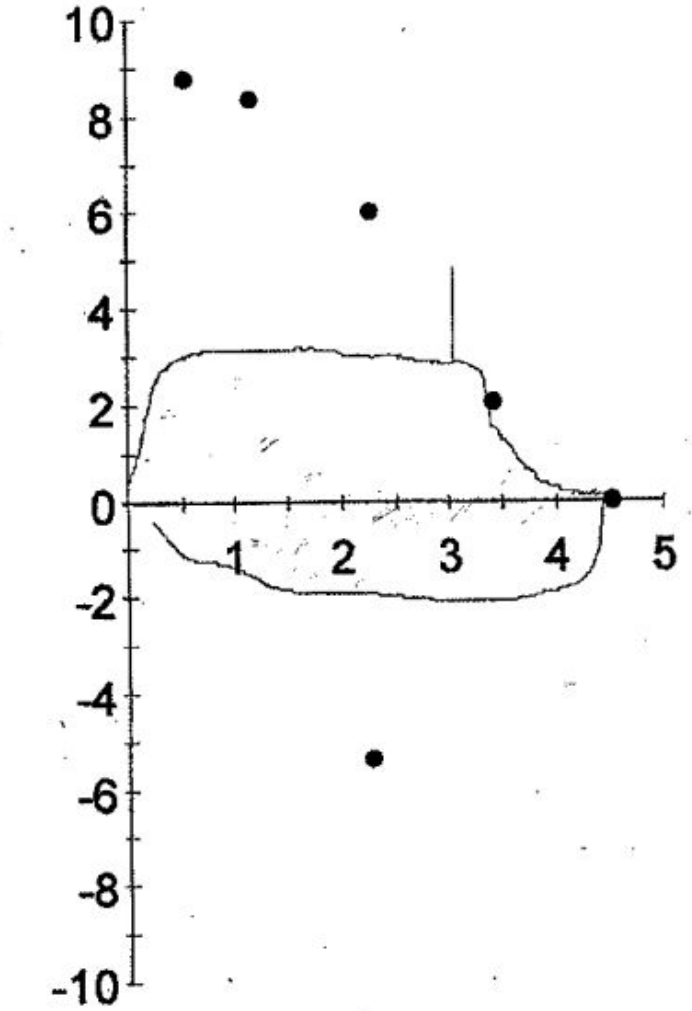
# Interpreting WEIRD Spirometry

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**Associate Professor**

**Department of Respiratory Care**

**Texas State University – Round Rock Campus**

# Disclosures

- President, Association of Asthma Educators
- Presenter has a financial relationship with Health.edu and ContinuED.com
- Director, NIOSH Spirometry Training Center – Texas State University
- This presentation does not focus exclusively on any specific product or service

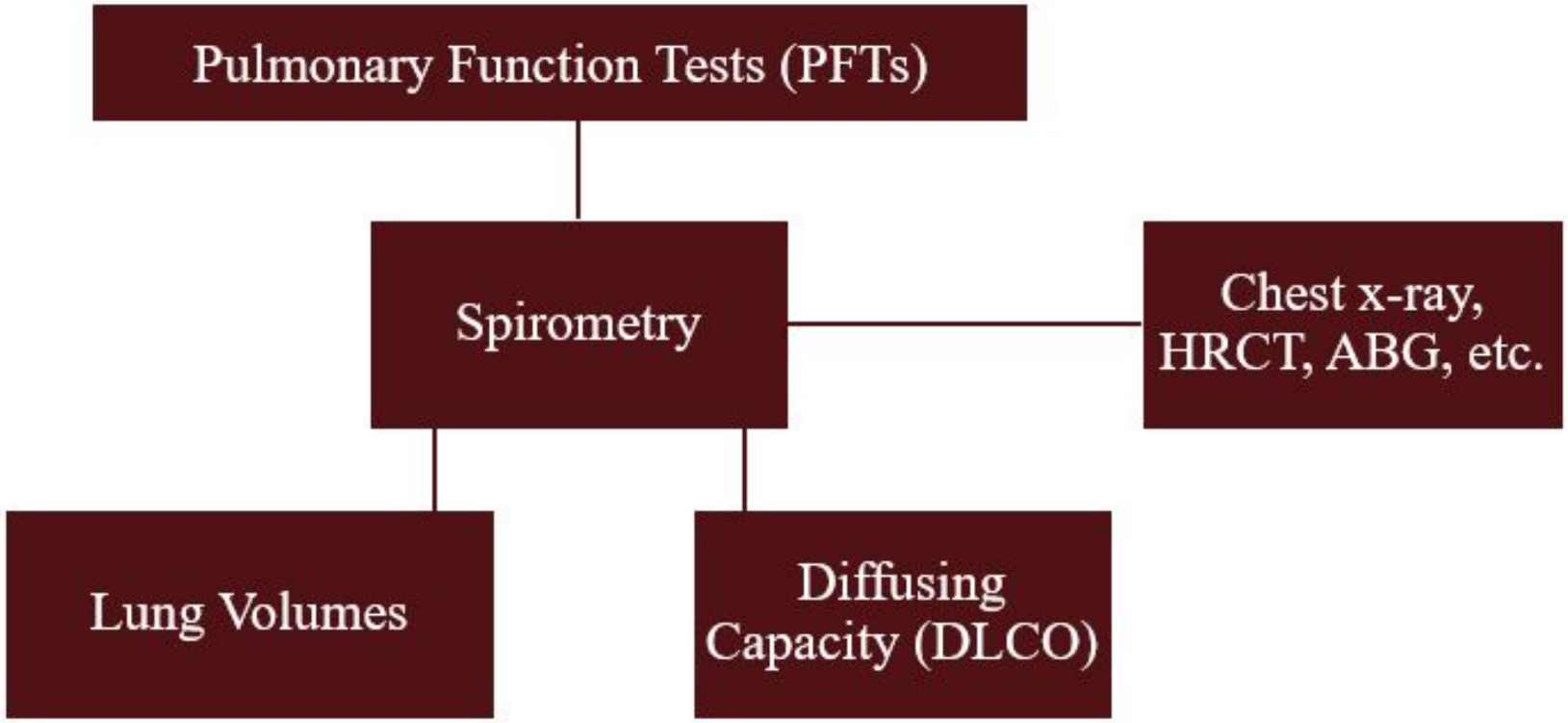
# Objectives

At the end of this presentation participants will be able to . . . .

- Recognize the important components of the American Thoracic Society's guidelines for spirometry testing
- Classify normal versus abnormal spirograms
- Identify the strategies used in spirometry interpretation

# Pulmonary Function Testing



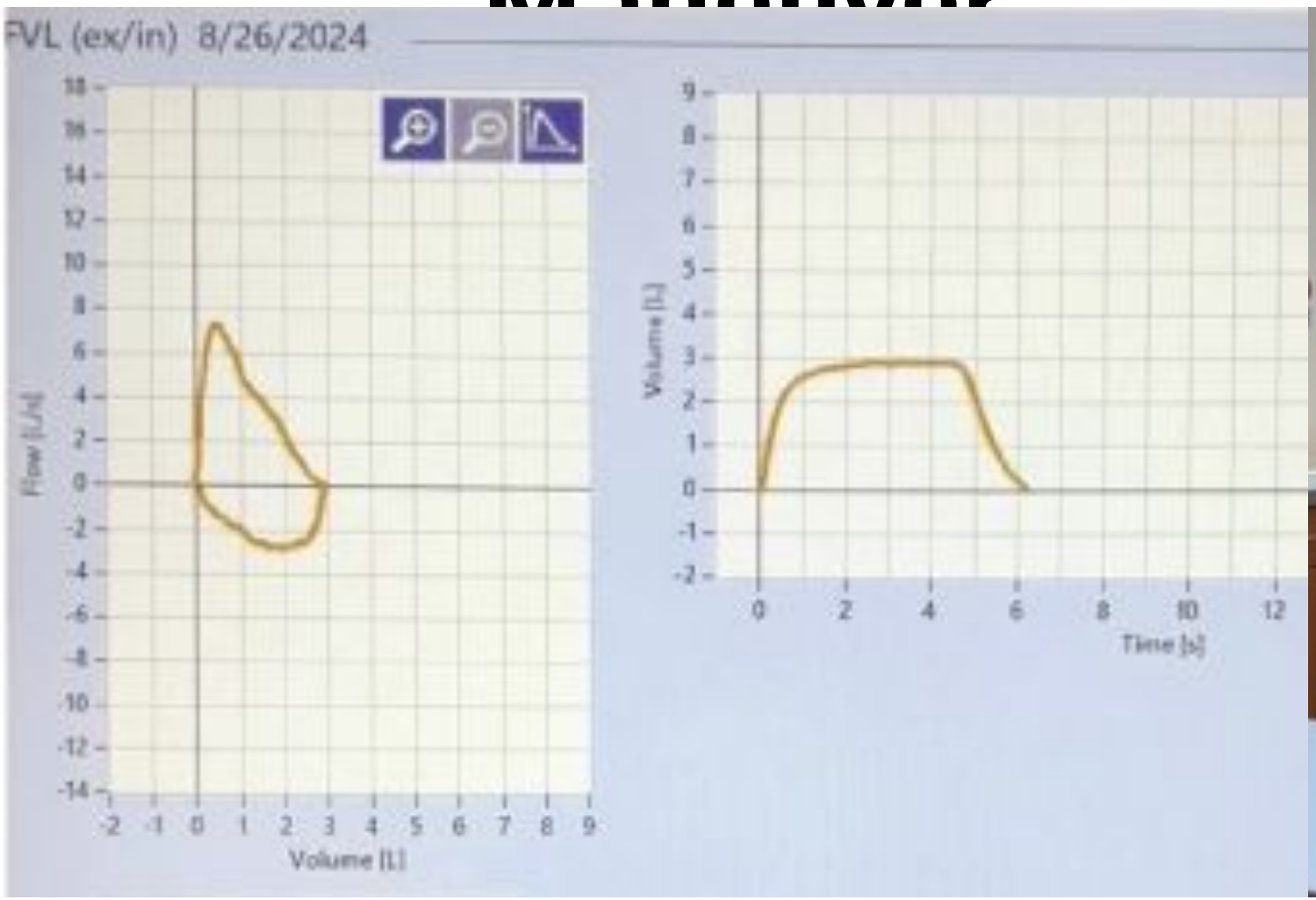



Am J Respir Crit Care Med Vol 200, Iss 8, pp 963–971, Oct 15, 2019

# Spirometry Maneuver

# Spirometry Maneuver





**ATS Criteria: 3 acceptable & repeatable spirometry maneuvers = Spirometry Test**

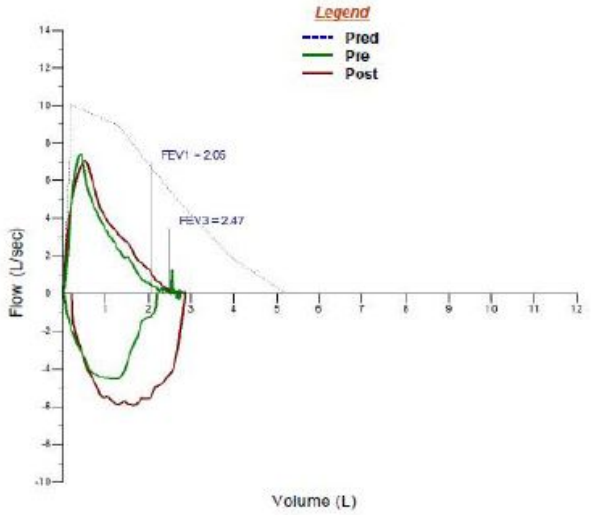
**1) Patient Demographics & Medical History:**

**2)**

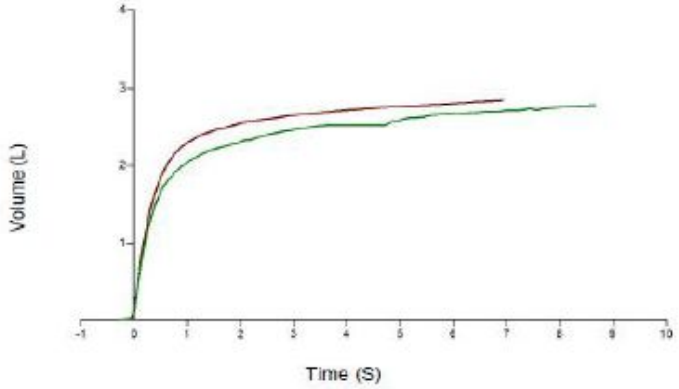
**Spirometry (BTPS)**

Pre Bronchodilator

| | | Actual | LLN | ULN | Predicted | % Pred | Z-score |
|---|---|---|---|---|---|---|---|
| StartTime | | 11:04 | ---- | ---- | ---- | ---- | ---- |
| FVC | L | 2.82 | 3.93 | 6.54 | 5.23 | 54 | -3.07 |
| $FEV_1$ | L | 2.05 | 2.91 | 4.92 | 3.94 | 52 | -2.90 |
| $FEV_1$ / FVC | % | 73 | 63 | 87 | 76 | 96 | -0.39 |
| $FEF_{25-75}$ | L/s | 1.24 | 1.39 | 5.26 | 3.01 | 41 | -1.84 |
| PEFR | L/s | 7.68 | 7.37 | 12.71 | 10.04 | 76 | ---- |

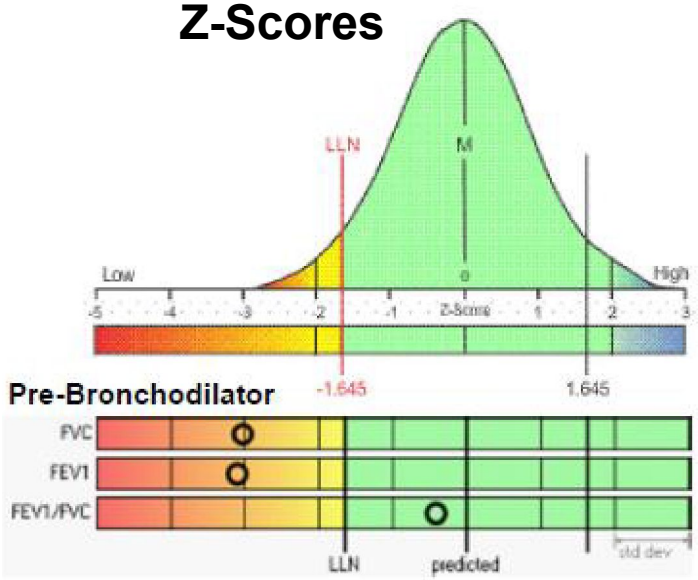



**Flow-Volume Loop**




**Volume-Time Curve**

**Bell Curve with Z-Scores**




**3) Technologist's Comments:**

**4) Interpretation:**

***LLN = -1.645**

***Lower Limit of Normal**

# Definition of Spirometry Indices

| Description | Abbreviation |
|---|---|
| Forced vital capacity | FVC (L) |
| Forced expiratory volume in 1 second | $FEV_1$ (L) |
| $FEV_1$/FVC ratio | $FEV_{1\%}$ --- |
| Forced expiratory flow during the middle half of the FVC | $FEF_{25-75}$ (L/s) |
| Forced Inspiratory Flow 50% | $FIF_{50}$ (L/s) |
| Forced Expiratory Flow 50% | $FEF_{50}$ (L/s) |
| Forced Inspiratory Vital Capacity | FIVC (L) |
| Peak expiratory flow rate | PEFR (L/s) |
| Forced expiratory time | FET (sec) |

McCormack MC, Stoller JD, & Hollingsworth, H. Overview of pulmonary function testing in adults. www.uptodate.com, May 27, 2020.

# *2019 ERS/ATS Standards for Spirometry



AMERICAN THORACIC SOCIETY DOCUMENTS

**Standardization of Spirometry 2019 Update**

An Official American Thoracic Society and European Respiratory Society Technical Statement

Brian L. Graham, Irene Steenbruggen, Martin R. Miller, Igor Z. Barjaktarevic, Brendan G. Cooper, Graham L. Hall, Teal S. Hallstrand, David A. Kaminsky, Kevin McCarthy, Meredith C. McCormack, Cristine E. Oropez, Margaret Rosenfeld, Sanja Stanojevic, Maureen P. Swanney†, and Bruce R. Thompson; on behalf of the American Thoracic Society and the European Respiratory Society

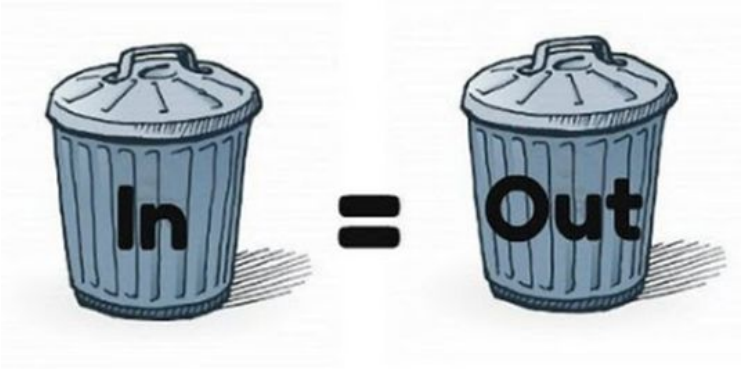
- Pre-Test Procedures:
  - Anthropometric measurements; Calibration, BTPS Correction, Reference Values, Pt. history, activities to avoid prior to testing.
- Spirometry acceptability and repeatability criteria for a valid test.
- Training and experience of the operator conducting spirometry testing.

***Ignore these standards at your own peril!**

# Spirometry: Accuracy versus Precision

**Accuracy -** the extent to which measurement of a known quantity results in approximating that quantity (i.e., volume and flow rates).

**Precision** - the extent to which repeated measurements of the same quantity can be reproduced (repeatability of FVC & $FEV_1$).

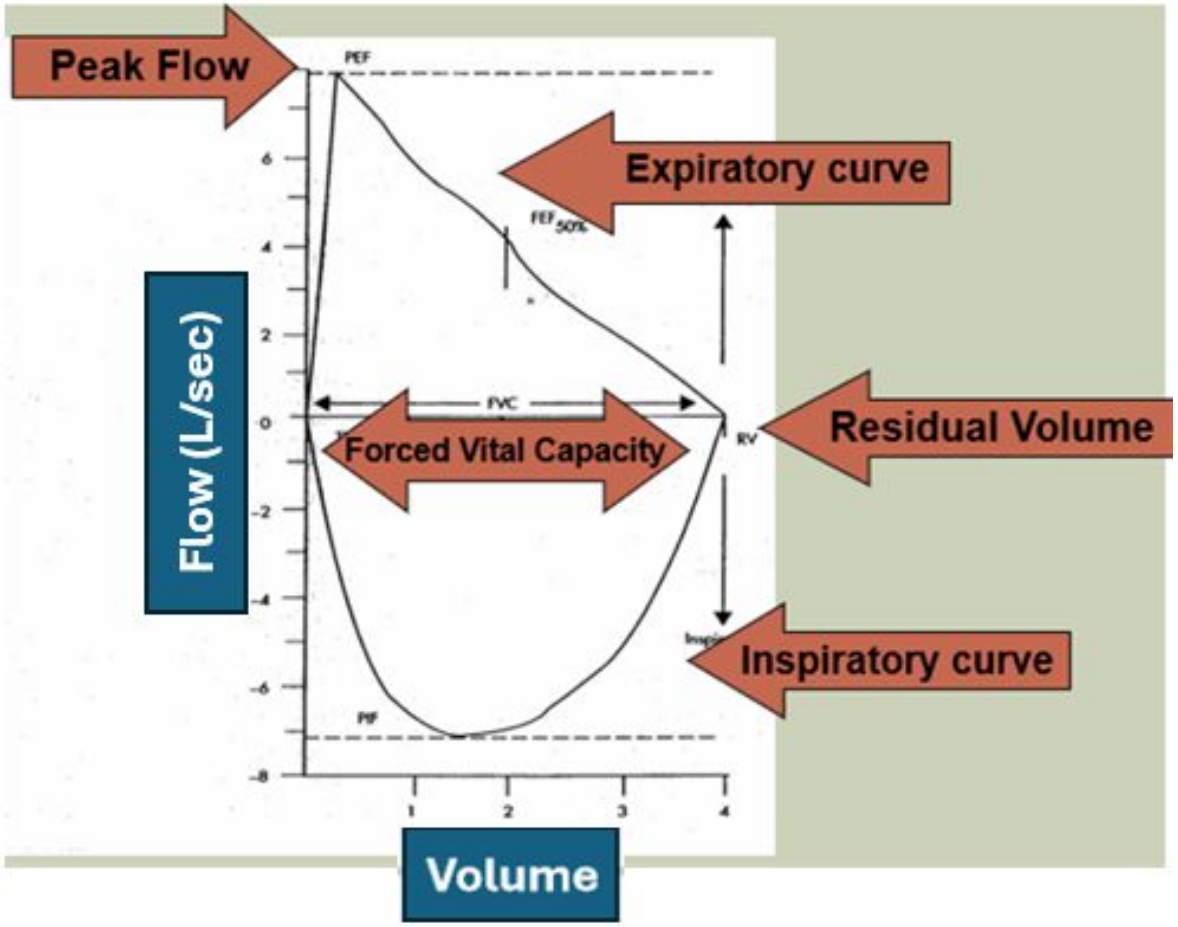


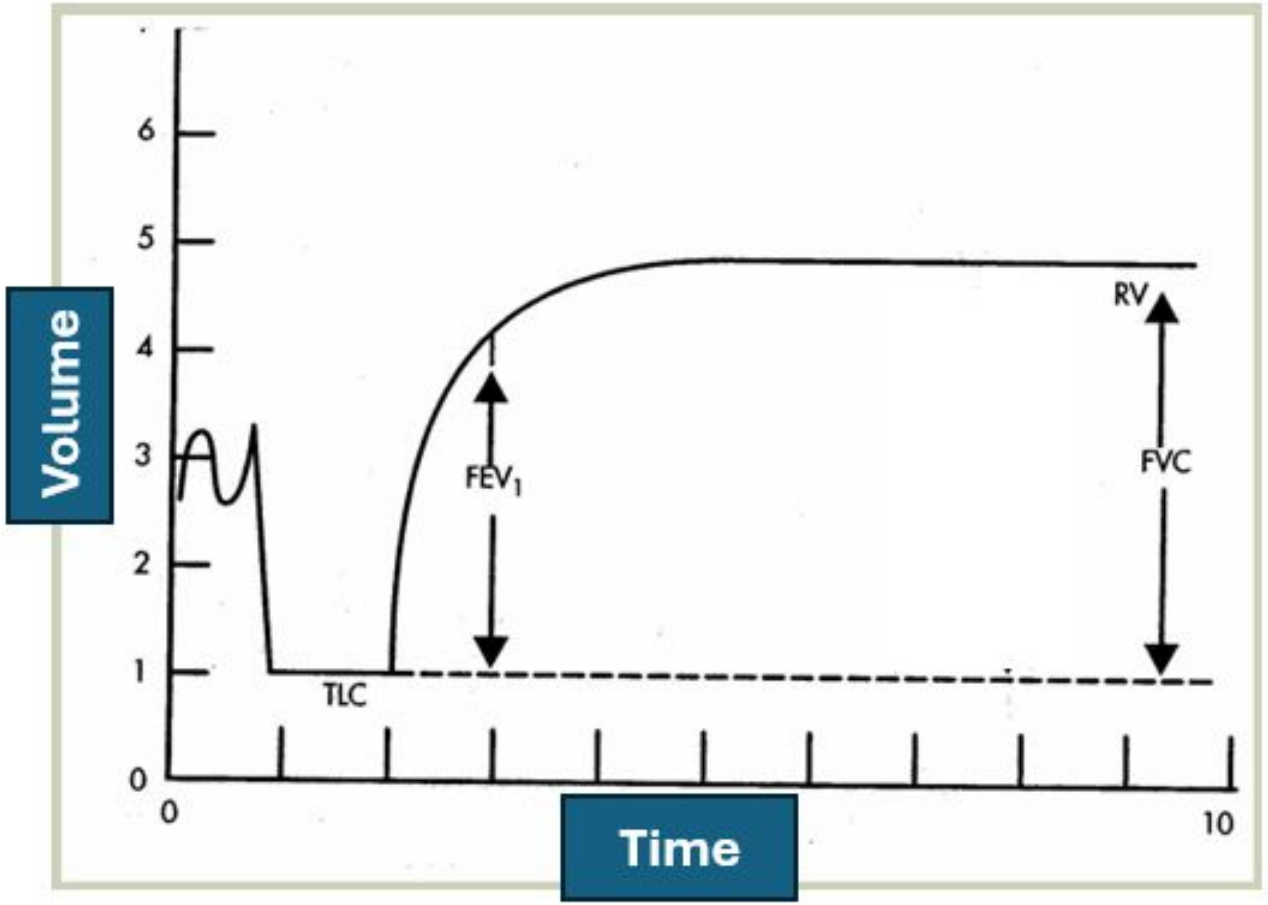
Stadiometer

# Who is conducting spirometry testing in your clinic?

# Spirometry: Normal Spirograms





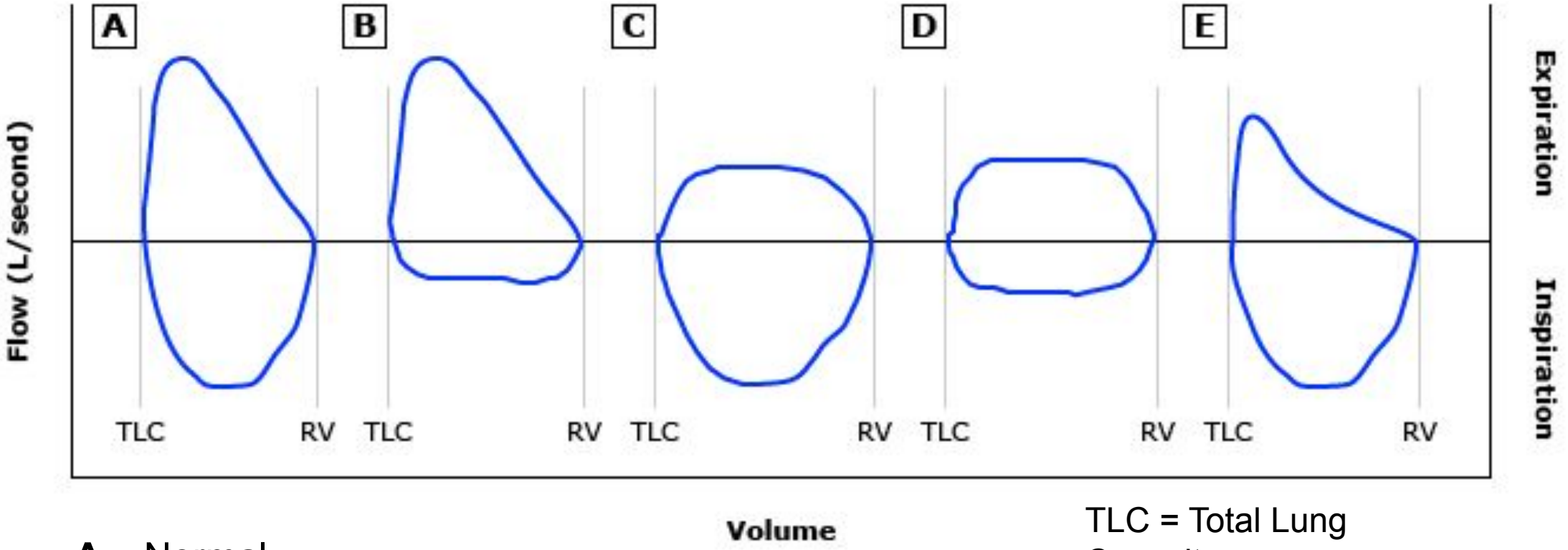




**Flow-Volume Loop**

**Volume-Time Curve**

# Flow-Volume Loops in Different Types of Physiologic Airway Obstruction






**A** = Normal
**B** = Variable extrathoracic obstruction
**C** = Variable intrathoracic obstruction
**D** = Fixed airway obstruction (intra or extrathoracic)
**E** = Lower airways obstruction

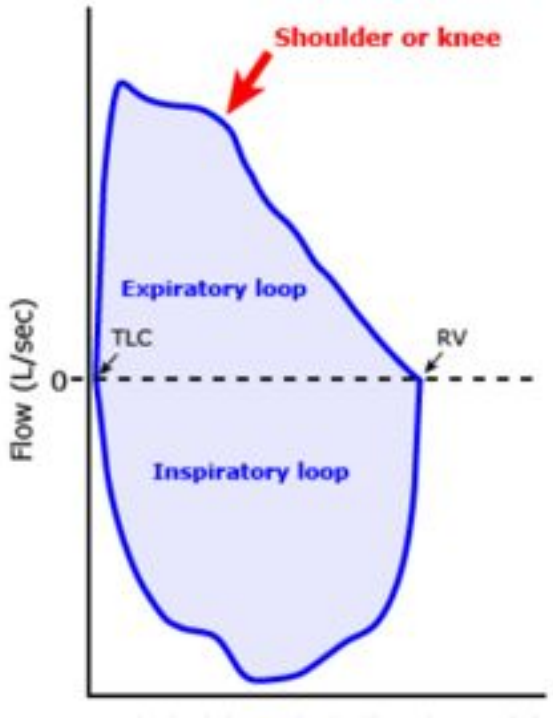
TLC = Total Lung Capacity
RV = Residual Volume

www.uptodate.com

# Identification of Flow-Volume Loops



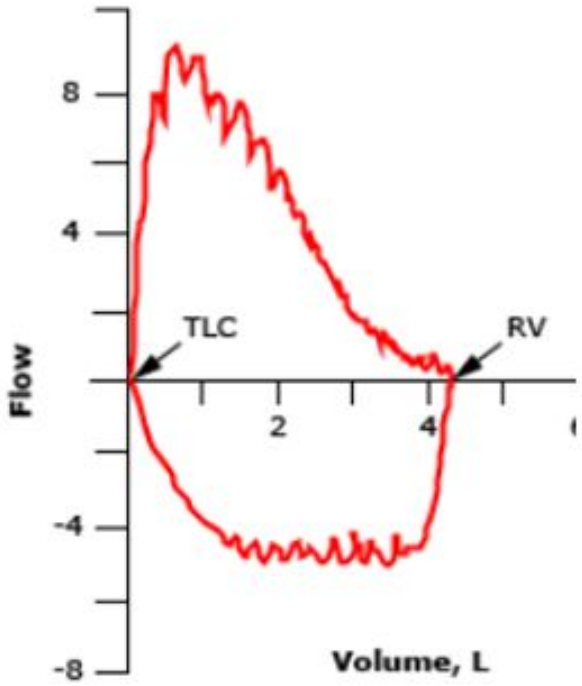
A




B

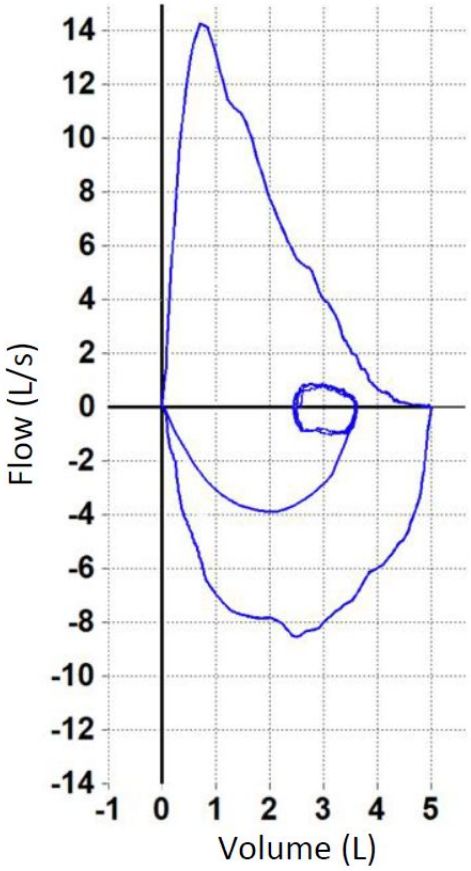
**A & B:** Flow-volume loops showing a "knee" pattern, which is a normal variant seen in young adults.

C



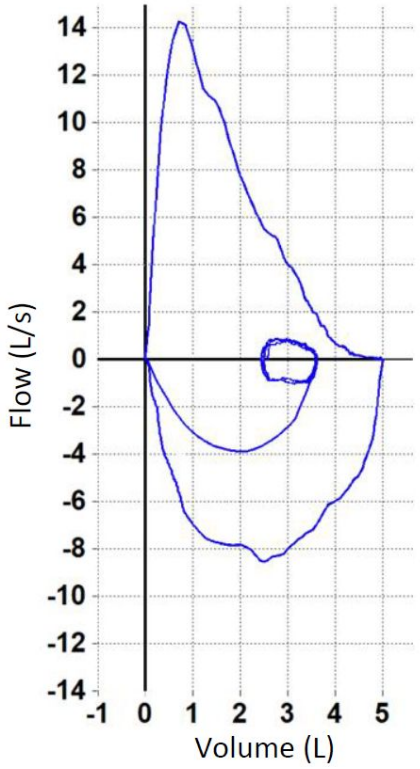

**C.** Obstructive sleep apnea showing a saw-tooth pattern.

D

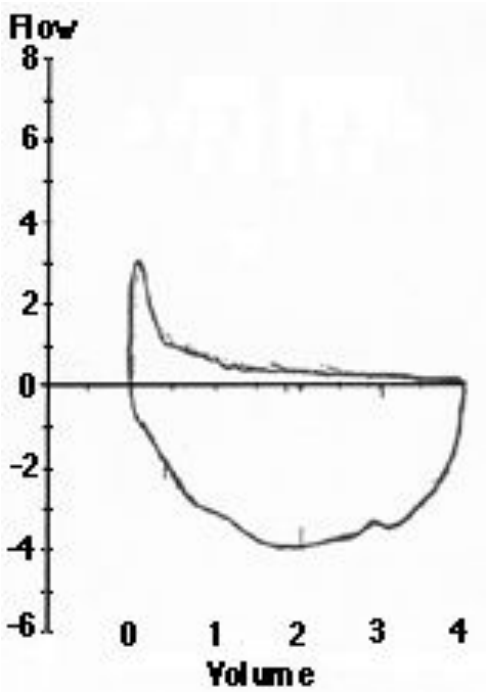



**D.** Suboptimal Inhalation (the expiratory curve does not match the inspiratory curve).

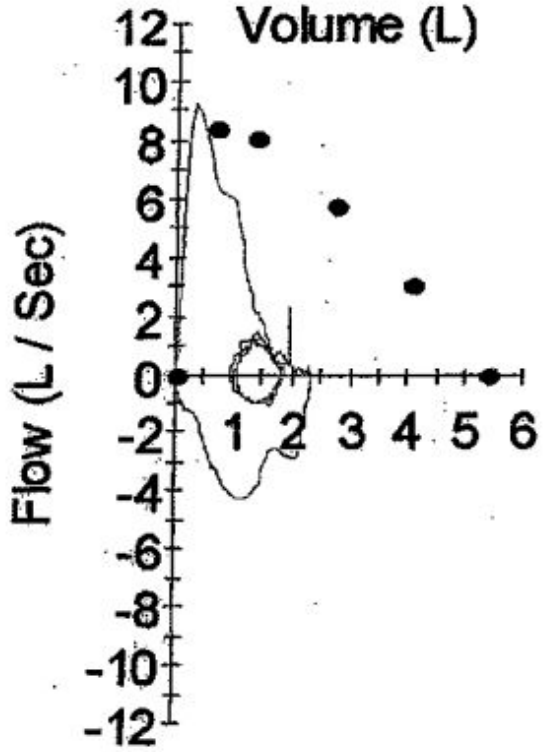
# Spirometry: Abnormal Flow-Volume Loops



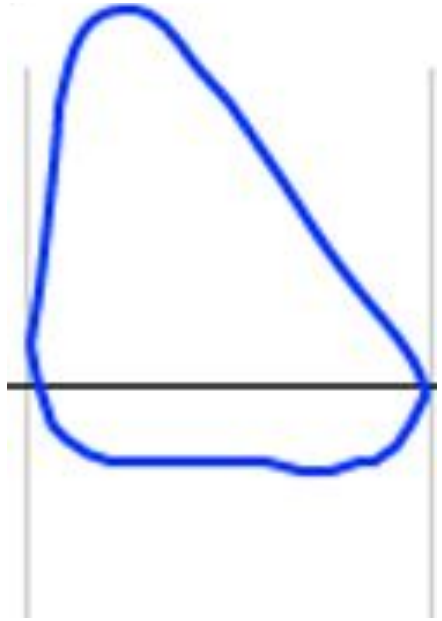

**Normal**




**Obstruction (Lung Impairment)**



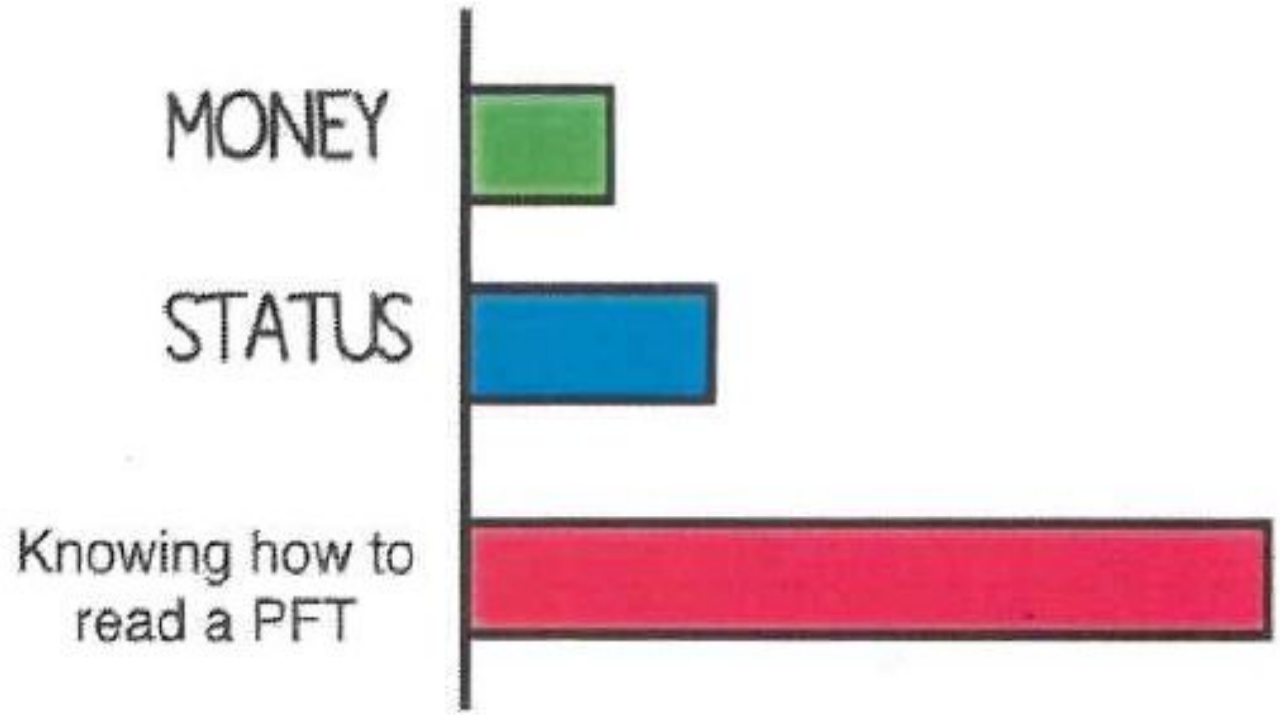

**Restriction (Lung Impairment)**



**Extrathoracic (Upper Airway Impairment)**

# WHAT GIVES PEOPLE

# power



# Interpretative Strategies for Lung Function Tests

EUROPEAN RESPIRATORY JOURNAL
ERS OFFICIAL DOCUMENTS
S. STANOJEVIC ET AL.

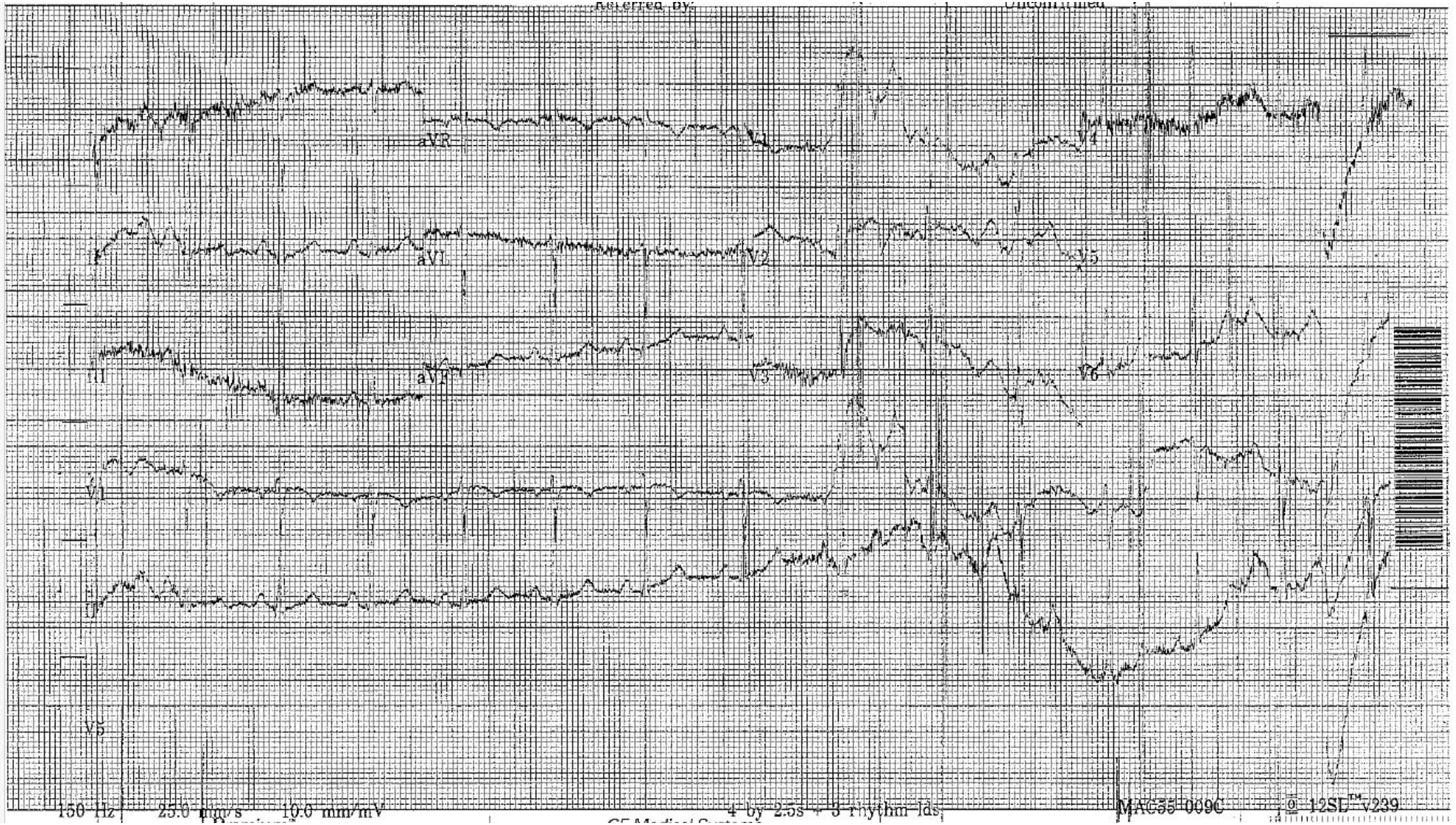
## ERS/ATS technical standard on interpretive strategies for routine lung function tests

Sanja Stanojevic[1], David A. Kaminsky[2], Martin R. Miller[3], Bruce Thompson[4], Andrea Aliverti[5], Igor Barjaktarevic[6], Brendan G. Cooper[7], Bruce Culver[8], Eric Derom[9], Graham L. Hall[10], Teal S. Hallstrand[8], Joerg D. Leuppi[11,12], Neil MacIntyre[13], Meredith McCormack[14], Margaret Rosenfeld[15] and Erik R. Swenson[8,16]

Stanojevic S, Kaminsky DA, Miller MR, et al. ERS/ATS technical standard on interpretive strategies for routine lung function tests. Eur Respir J 2022; 60: 2101499 [DOI: 10.1183/13993003.01499-2021]

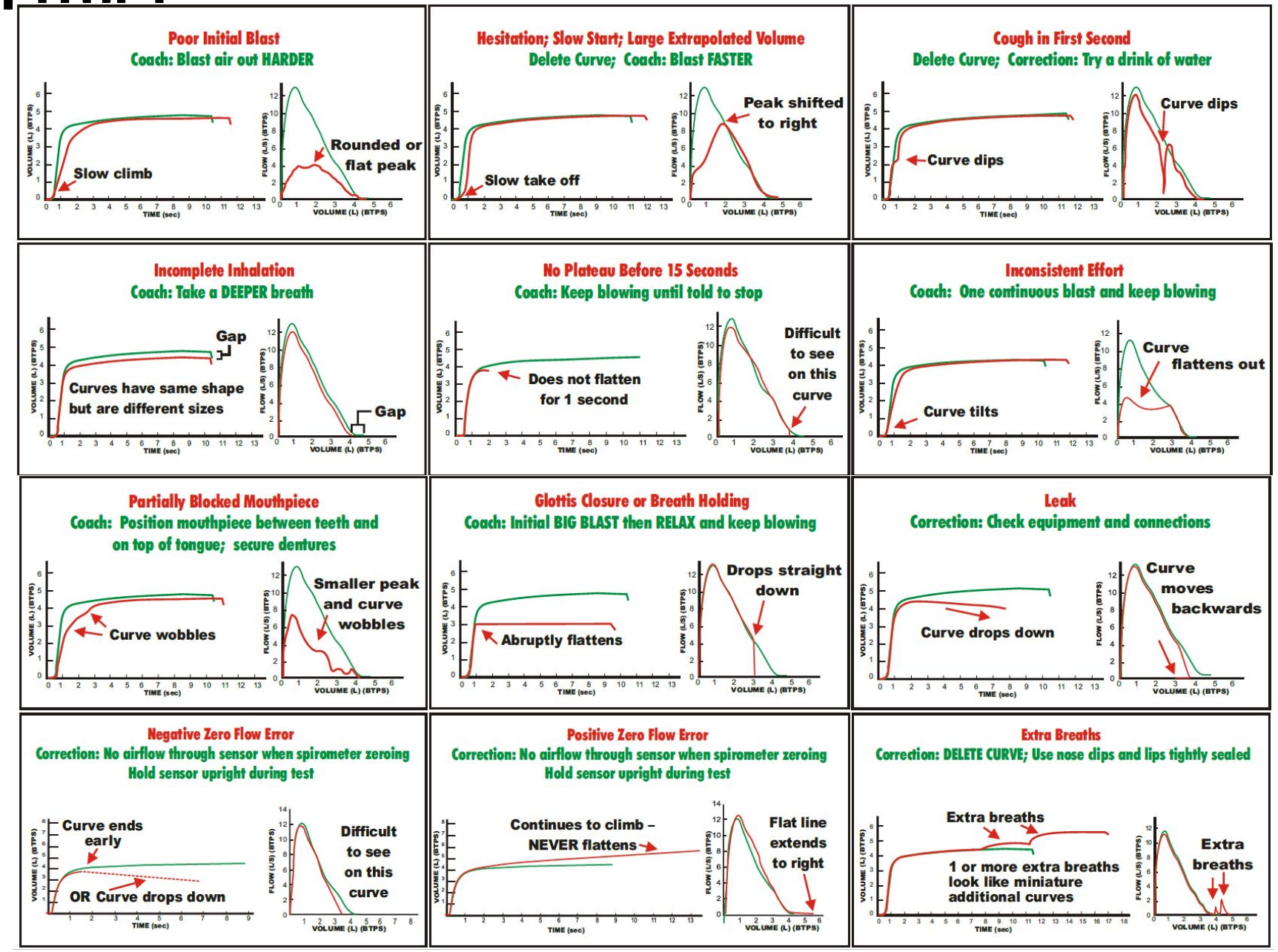
# Interpretation of Results: 12-Lead EKG





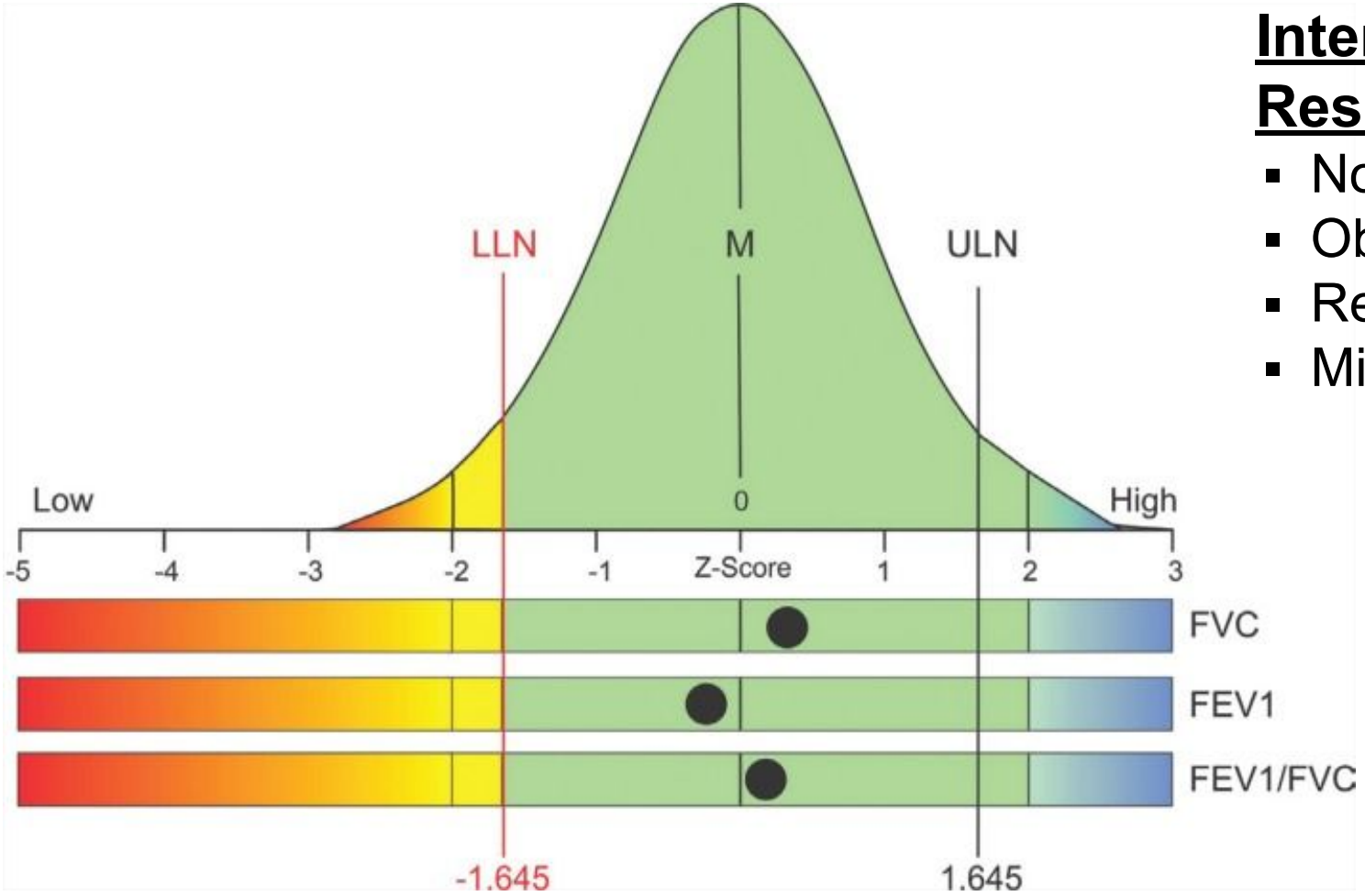
# Interpretation of Results: Spirometry Technical Errors





# Interpretation of Lung Function Tests: Z-Scores and the Lower Limit of Normal (LLN)






## Interpretation of Spirometry Results

- Normal
- Obstruction
- Restriction
- Mixed Pattern

} Lung Impairment

## Lung Impairment

Mild: −1.645 to −2.5

Moderate: −2.51 to −4.0

Severe: Less than −4.1

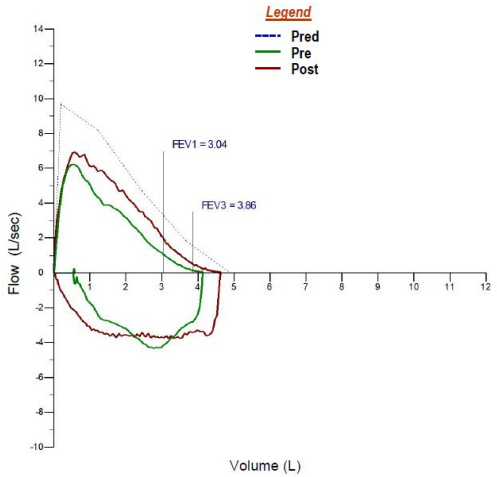
Stanojevic S, Kaminsky DA, Miller MR, et al. ERS/ATS technical standard on interpretive strategies for routine lung function tests. Eur Respir J 2022; 60: 2101499 [DOI: 10.1183/13993003.01499-2021]

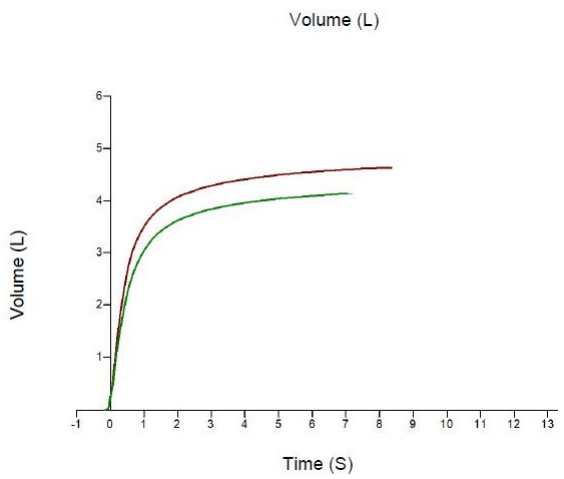
# Spirometry Report



## Caucasian male, age 52; Predicted equation: GLI (Quanjer) 2012

| Spirometry (BTPS) | | Pre Bronchodilator Actual | LLN | ULN | Predicted | % Pred | Z-score |
|---|---|---|---|---|---|---|---|
| StartTime | | | ---- | ---- | ---- | ---- | ---- |
| FVC | L | 4.13 | 3.81 | 6.01 | 4.90 | 84 | -1.16 |
| $FEV_1$ | L | 3.04 | 2.97 | 4.67 | 3.84 | 79 | -1.53 |
| $FEV_1$ / FVC | % | 74 | 67 | 88 | 79 | 94 | -0.72 |
| $FEF_{25-75}$ | L/s | 2.38 | 1.80 | 5.56 | 3.42 | 70 | -0.99 |
| PEFR | L/s | 6.23 | 7.37 | 12.01 | 9.69 | 64 | ---- |



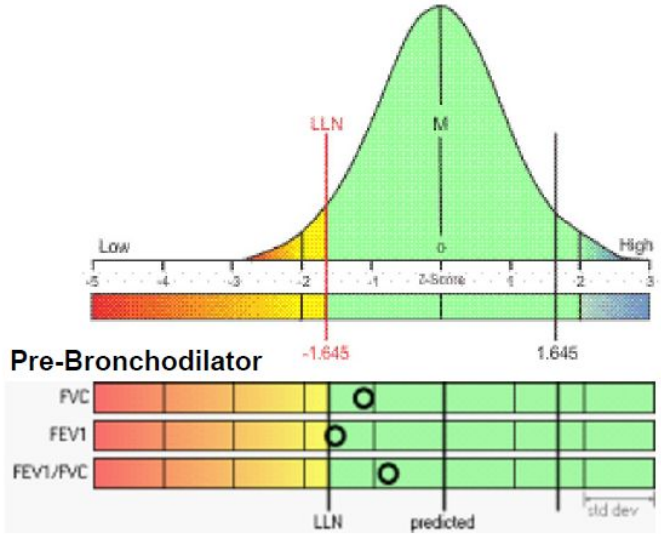

**Lung Impairment**

Mild: −1.645 to −2.5

Moderate: −2.51 to −4.0

Severe: Less than −4.1

**Interpretation:**
**Normal spirometry**



# Spirometry: Chief Complaint = Asthma Symptoms



**21-year-old, Hispanic female; Dx: Mild Persistent Asthma; Predicted Equation: GLI (Quanjer) 2012**

Test1 10/25/2023 13:28

| Parameter | Best | LLN | Z-sc. | %Pred | Pred | Trial3 | Trial1 | Trial2 |
|---|---|---|---|---|---|---|---|---|
| FVC[L] | 3.14 | 2.45 | 0.33 | 103.9 | 3.03 | 3.14 | 3.06 | 3.04 |
| FEV1[L] | 2.60 | 2.17 | -0.29 | 96.5 | 2.70 | 2.60 | 2.53 | 2.53 |
| FEV1/FVC | 0.83 | 0.79 | -1.02 | | 0.89 | 0.83 | 0.83 | 0.83 |
| FEF2575[L/s] | 2.56 | 2.24 | | 75.8 | 3.38 | 2.56 | 2.45 | 2.54 |
| PEF[L/s] | 6.58 | – | | – | – | 6.58 | 6.54 | 6.32 |

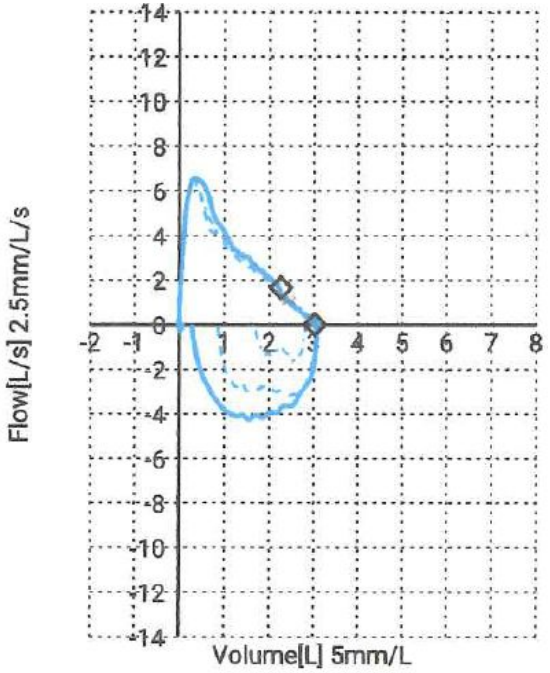
**Interpretation: Normal**

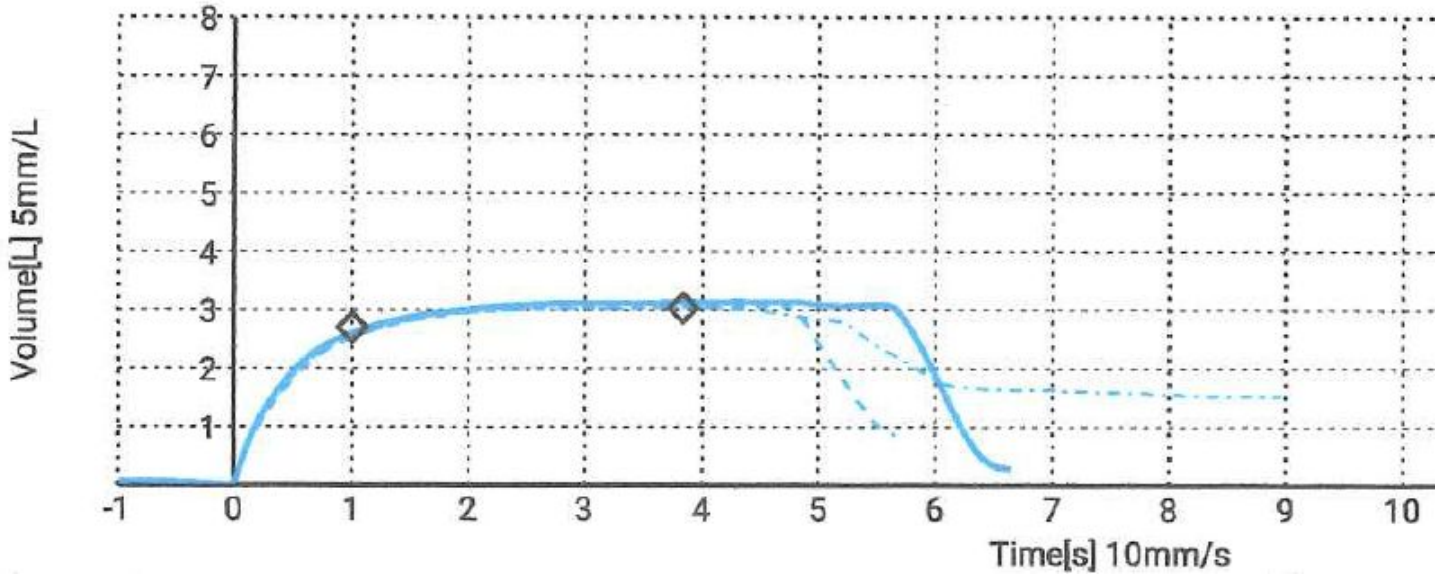
**Lung Impairment**

Mild: −1.645 to −2.5

Moderate: −2.51 to −4.0

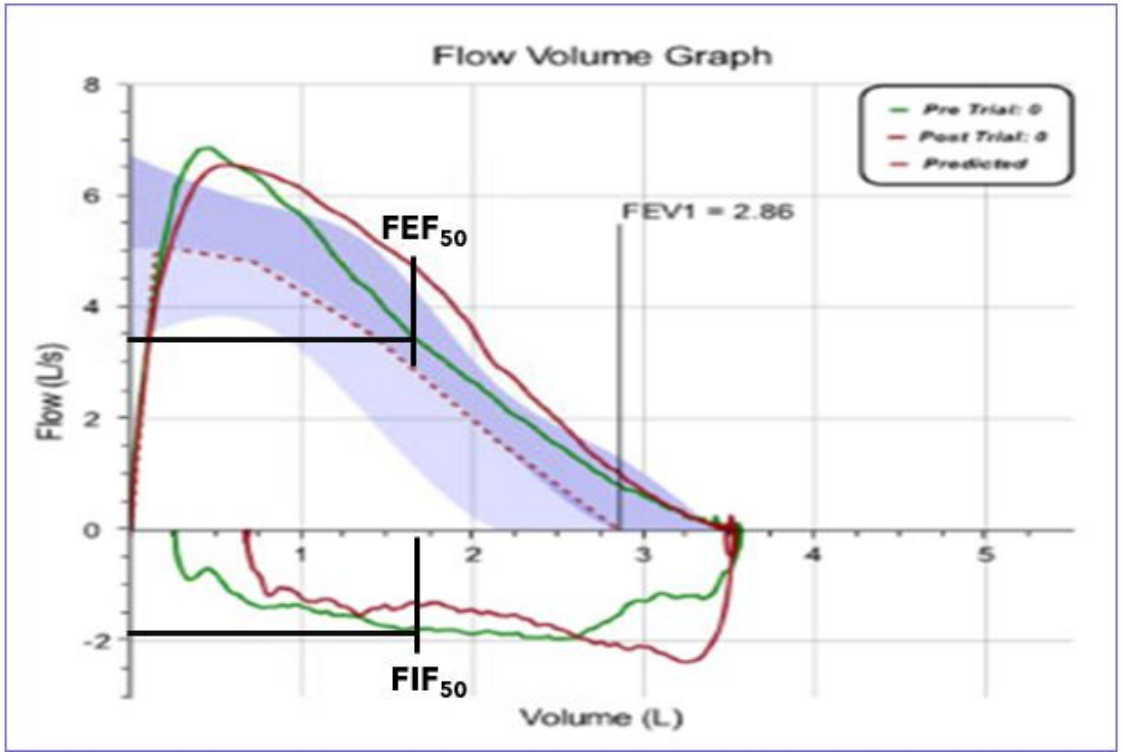
Severe: Less than −4.1



# Spirometry: **13-year-old, Hispanic female; no previous diagnosis of asthma.** Chief Complaint = Dyspnea

| | | Pre-Bronchodilator | | | | |
|---|---|---|---|---|---|---|
| Parameter | Units | Result | LLN | ULN | Z-score | %Pred |
| FVC | L | 3.57 | 2.30 | 3.42 | 2.07 | 125 |
| $FEV_1$ | L | 2.86 | 2.05 | 3.03 | 1.05 | 112 |
| $FEV_1$ / FVC | % | 80 | 79 | 98 | -1.52 | 89 |
| $FEF_{25-75}$ | L/s | 2.71 | 2.15 | 4.43 | -0.78 | 84 |
| PEFR | L/s | 6.86 | 3.39 | 6.73 | --- | 136 |
| FET | s | 6.68 | 6.00 | --- | --- | --- |
| BEV | L | 0.07 | --- | --- | --- | --- |
| PIFR | L/s | 3.22 | --- | --- | --- | 96 |
| $FEF_{50}/FIF_{50}$ | | 174 | --- | --- | --- | --- |
| Reference: GLI 2017 | Test Quality: | Pre BD: FEV1 = A, FVC = A | | | | |




**1st Provider's Interpretation: Normal Spirometry**

**2nd Provider's Interpretation: Vocal Cord Dysfunction**

Flow-Volume Loop reveals reduced flows on inspiration ($FIF_{50\%}$), i.e., Extrathoracic Obstruction.

# Spirometry Results: Post-COVID

Name: **Anonymous Doe** MRN: ****** Sex: **F** DOB:**7/30/1967** Age: **54** Race: **C**

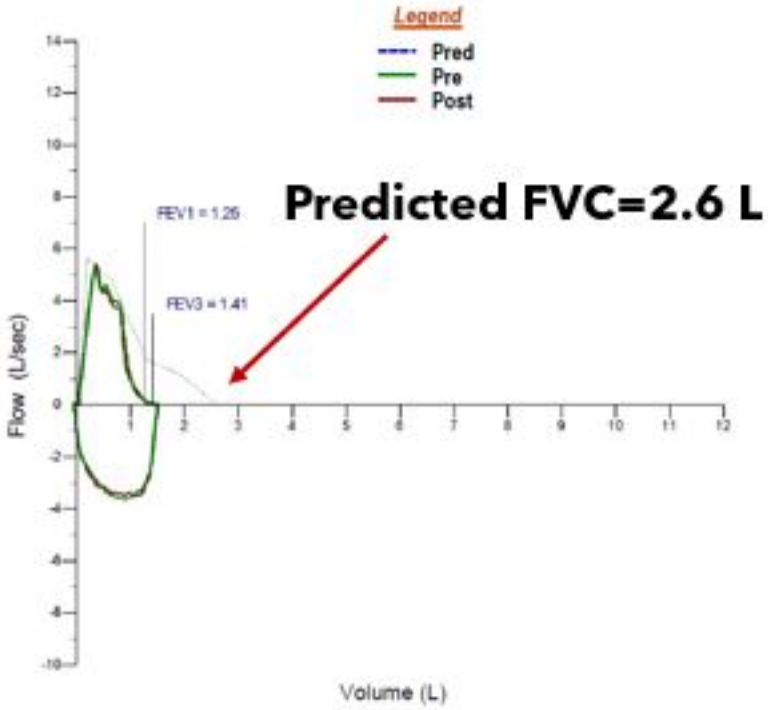
Height: **57.3 in** Weight: **215 lb** BMI: **46.1**

ICD-10 **Chronic respiratory failure with hypoxia**

***Spirometry (BTPS)***

**Pre Bronchodilator**

| | | Actual | LLN | ULN | Predicted | % Pred | Z-score |
|---|---|---|---|---|---|---|---|
| StartTime | | 10:13 | ---- | ---- | ---- | ---- | ---- |
| FVC | L | 1.49 | 2.01 | 3.22 | 2.60 | 57 | -3.17 |
| $FEV_1$ | L | 1.25 | 1.62 | 2.57 | 2.10 | 60 | -2.86 |
| $FEV_1$ / FVC | % | 84 | 69 | 91 | 81 | 104 | 0.48 |
| $FEF_{25-75}$ | L/s | 1.78 | 1.18 | 3.46 | 2.17 | 82 | -0.59 |
| PEFR | L/s | 5.26 | 4.25 | 7.01 | 5.63 | 93 | ---- |




**Flow-Volume Loop**

Interpretation: Moderate restriction.

**Lung Impairment**

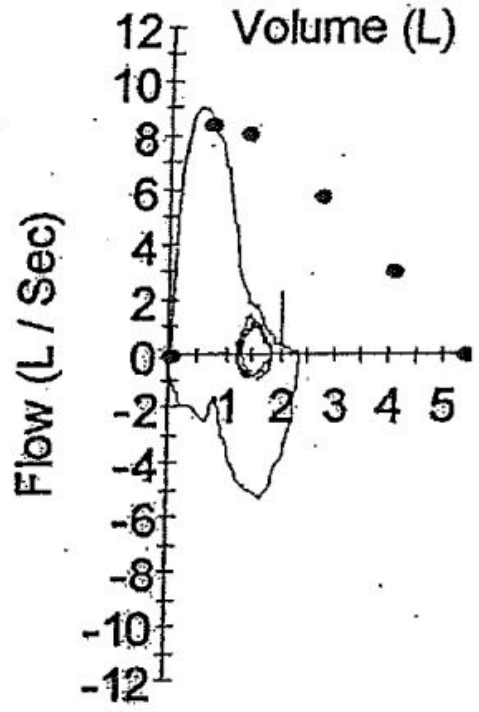
Mild: −1.645 to −2.5

Moderate: −2.51 to −4.0

Severe: Less than −4.1

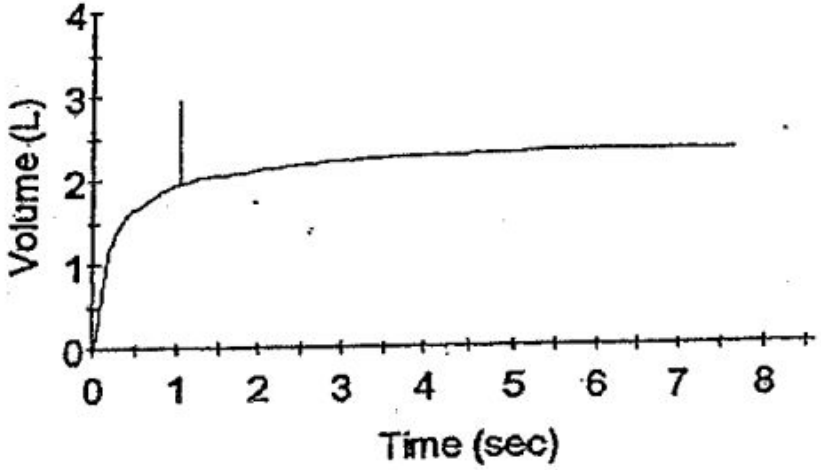
# Spirometry: Restrictive Lung Impairment

| SPIROMETRY | Pred. | Actual | %Pred. |
|---|---|---|---|
| FVC (L) | 6.36 | 2.32 | 37 |
| FEV1 (L) | 5.00 | 2.01 | 40 |
| FEV1/FVC (%) | 79 | 87 | 110 |
| FEF 25-75% (L/sec) | 5.14 | 2.90 | 56 |
| FEF Max (L/sec) | 11.21 | 10.03 | 90 |




<u>Characteristics of a Restrictive Pattern</u>

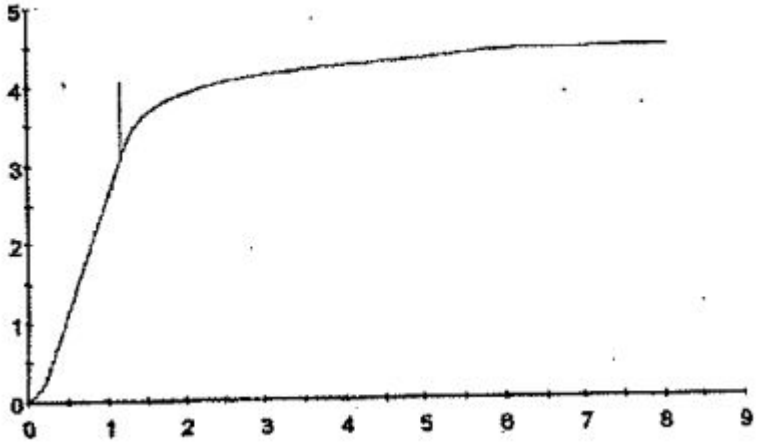
- Volumes are proportionally reduced
- Increased $FEV_1$/FVC ratio
- Normal or near normal flow rates



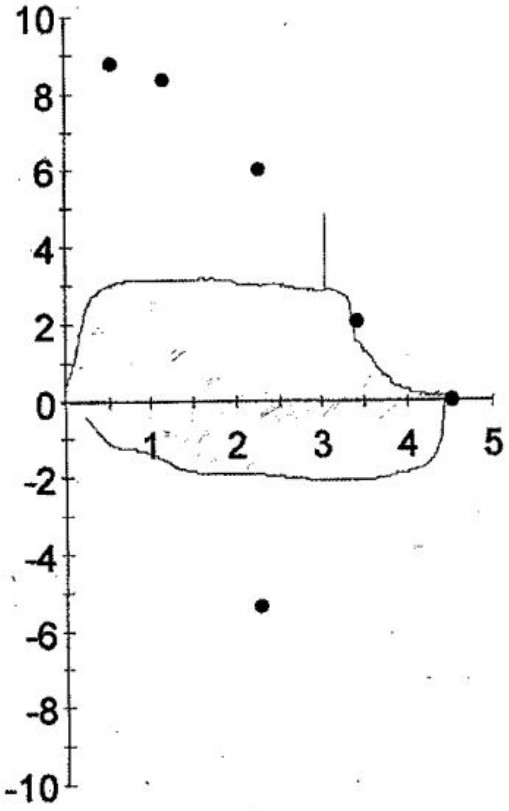
# Spirometry: Fixed Airway Obstruction

**PRE-BRONCH**

| | Actual | Pred. | %Pred. |
|---|---|---|---|
| **SPIROMETRY** | | | |
| FVC (L) | 4.46 | 4.55 | 98 |
| FEV1 (L) | 3.06 | 3.61 | 85 |
| FEV1/FVC (%) | 69 | 79 | 87 |
| FEF 25% (L/sec) | 3.11 | 8.37 | 37 |
| FEF 50% (L/sec) | 2.97 | 6.05 | 49 |
| FEF 75% (L/sec) | 2.40 | 2.04 | 118 |
| FEF 25-75% (L/sec) | 2.98 | 3.97 | 75 |
| FEF Max (L/sec) | 3.15 | 8.74 | 36 |
| FIVC (L) | 4.21 | | |
| FIF 50% (L/sec) | 1.97 | 5.34 | 37 |
| FIF Max (L/sec) | 2.13 | | |




Volume-Time Curve




Flow-Volume Loop

Characteristics of Fixed Airway Obstruction

- Reduced inspiratory ($FIF_{50\%}$) & expiratory flows ($FEF_{50\%}$)
- Flattened Flow-Volume Loop
- Normal or near normal exhaled volume (i.e., FVC)

# Spirometry: Before and After Bronchodilator Study



Name: **Anonymous Doe** MRN: ****** Sex: **F** DOB:**10/3/1985** Age: **37** Race: **C**

Height: **66 in** Weight: **290 lb** BMI: **46.9**

ICD-10 **Moderate persistent asthma, uncomplicated**

Tech: **Jeff Haynes RRT RPFT FAARC** Attending: **M F. Mirza, M.D.** Referring: **Pamela Ali, M.D.**

**ATS/ERS compliant tests earn a ✔ : Spiro ✔ DLCO ✔ VTG** Predicteds: Spiro GLI 2012, DLCO GLI 2017, LV Quanjer

| ***Spirometry (BTPS)*** | | Pre Bronchodilator | | | | | | Post Bronchodilator | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Actual | LLN | ULN | Predicted | % Pred | Z-score | Actual | % Pred | Abs Chg | % Change | Z-score |
| StartTime | | 08:30 | ---- | ---- | ---- | ---- | ---- | 09:17 | ---- | ---- | -- | ---- |
| FVC | L | 2.96 | 3.19 | 4.82 | 3.99 | 74 | -2.12 | 4.15 | 104 | 1190 mL | 40 | 0.33 |
| $FEV_1$ | L | 1.74 | 2.62 | 3.91 | 3.28 | 53 | -3.73 | 3.01 | 92 | 1270 mL | 73 | -0.67 |
| $FEV_1$ / FVC | % | 59 | 72 | 92 | 83 | 71 | -3.05 | 73 | 88 | ---- | 24 | -1.45 |
| $FEF_{25-75}$ | L/s | 0.86 | 2.11 | 4.98 | 3.42 | 25 | -3.73 | 2.17 | 63 | 1.31 L/s | 152 | -1.56 |
| PEFR | L/s | 3.85 | 5.50 | 9.16 | 7.33 | 53 | ---- | 6.96 | 95 | 3.11 L/s | 81 | ---- |

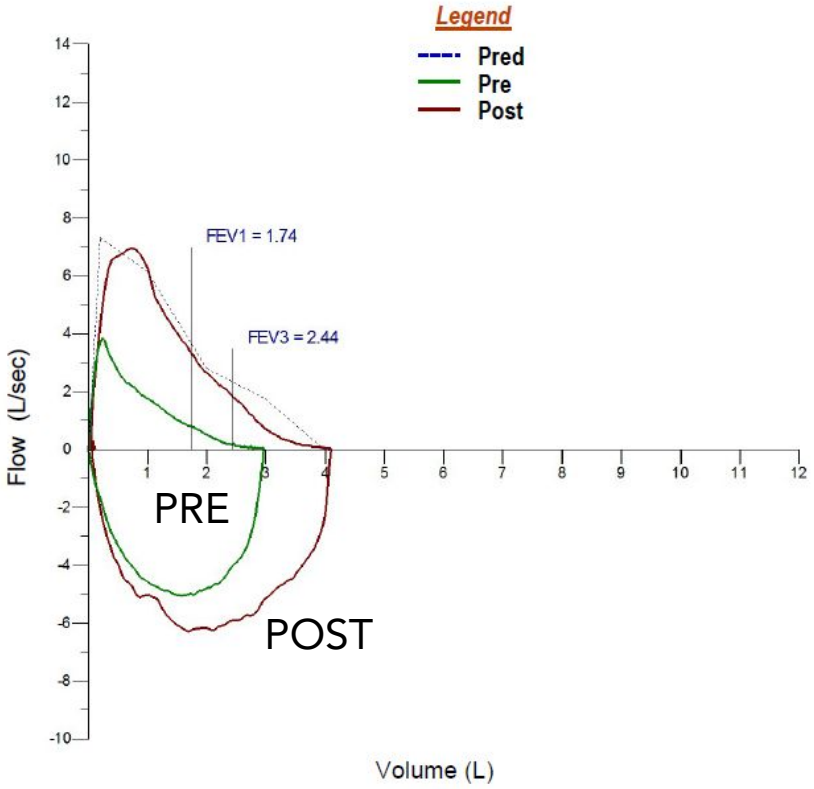
Interpretation: Moderate obstruction with a significant response to the bronchodilator.

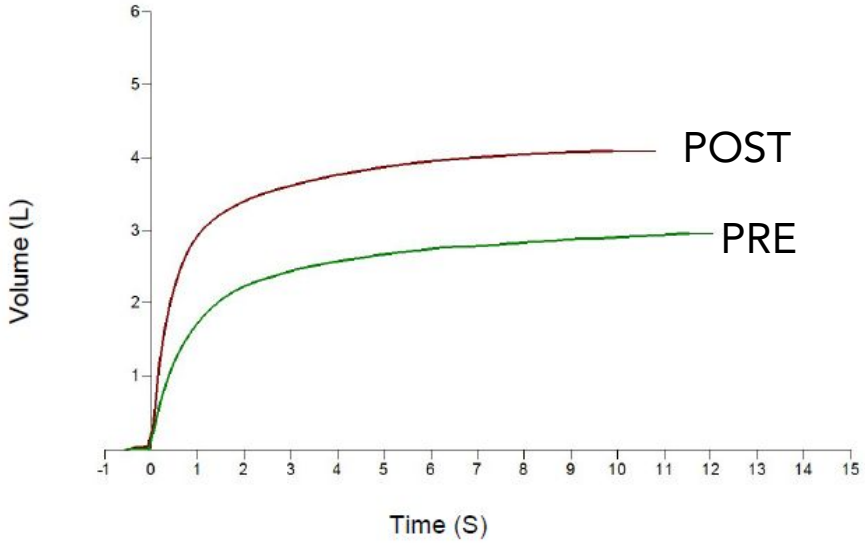
# Spirometry: Before and After Bronchodilator Study

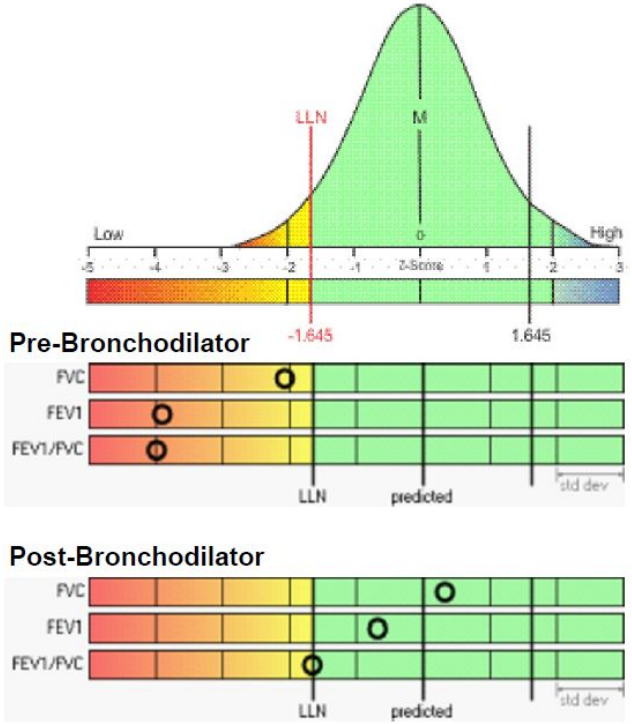
Name: **Anonymous Doe** MRN: ****** Sex: **F** DOB:**10/3/1985** Age: **37** Race: **C**

Height: **66 in** Weight: **290 lb** BMI: **46.9**

ICD-10 **Moderate persistent asthma, uncomplicated**



# Spirometry: Severe Obstruction



Name: **Anonymous Doe** MRN: ******* Sex: **F** DOB:**4/1/1962** Age: **60** Race: **C**

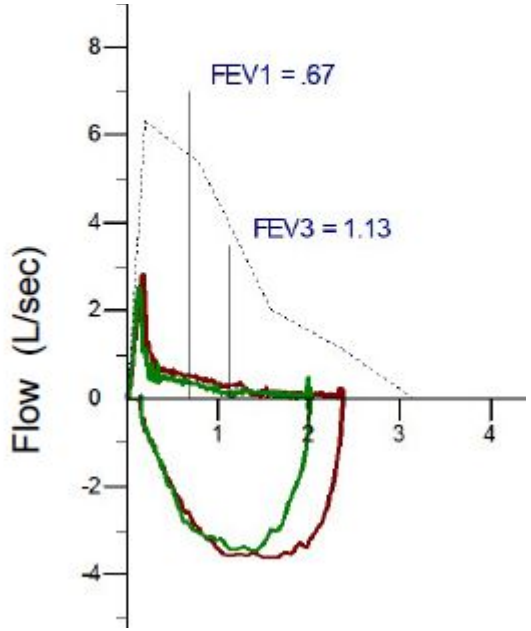
Height: **64 in** Weight: **92 lb** BMI: **15.8**

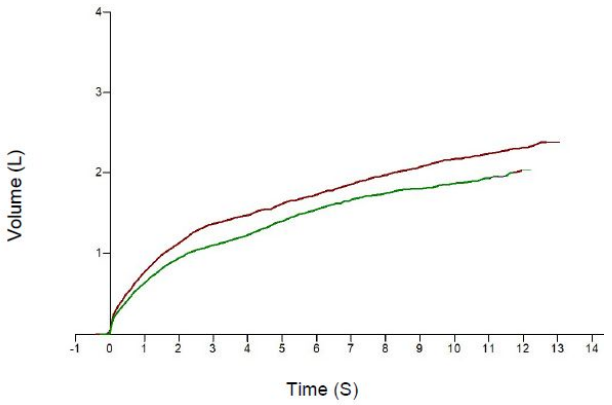
ICD-10 **Chronic obstructive pulmonary disease, unspecified**

***Spirometry (BTPS)***

**Pre Bronchodilator**

| | | Actual | LLN | ULN | Predicted | % Pred | Z-score |
|---|---|---|---|---|---|---|---|
| StartTime | | 13:09 | ---- | ---- | ---- | ---- | ---- |
| FVC | L | 2.03 | 2.40 | 3.97 | 3.16 | 64 | -2.46 |
| $FEV_1$ | L | 0.67 | 1.88 | 3.08 | 2.49 | 27 | -4.65 |
| $FEV_1$ / FVC | % | 33 | 67 | 90 | 79 | 42 | -4.71 |
| $FEF_{25-75}$ | L/s | 0.19 | 1.16 | 3.75 | 2.27 | 8 | -4.14 |
| PEFR | L/s | 2.89 | 4.60 | 8.04 | 6.32 | 46 | ---- |




Interpretation: Severe airways obstruction

**Lung Impairment**

Mild: −1.645 to −2.5

Moderate: −2.51 to −4.0

Severe: Less than −4.1

# Interpretative Strategies for Lung Function Tests

Interpretation of technically **acceptable** PFT results has three key aspects:

1) Classification of observed values as within/outside the normal range (i.e., reference equation).

2) Functional classification of the identified impairment (i.e., obstruction).

3) Integration of clinical data to inform the diagnosis and guide therapy.

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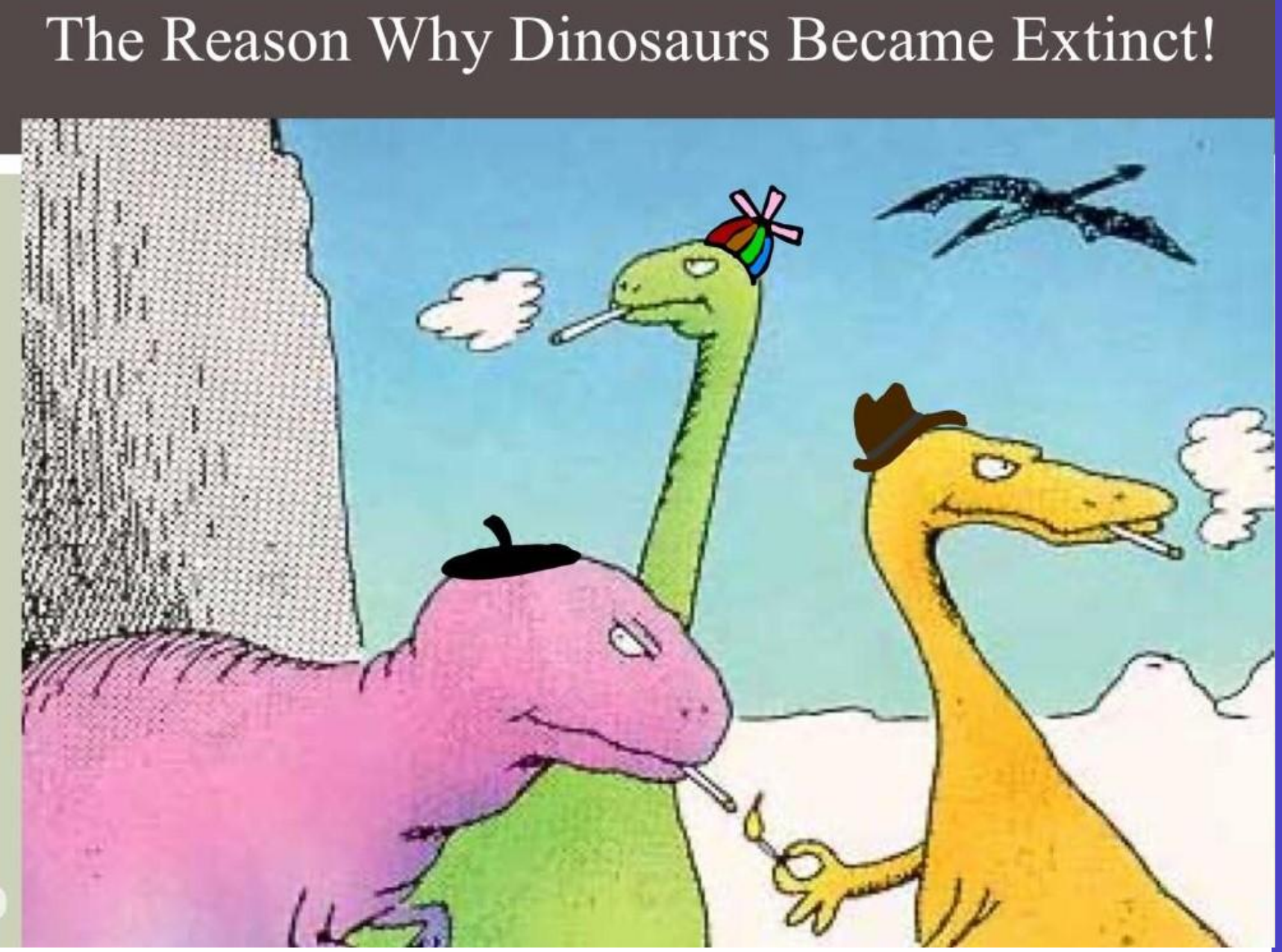


# QUESTIONS?

# Thank You!

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