Division of Pulmonary, Critical Care
& Sleep Medicine
University of Washington

PFT Interpretation for Internists & PCPs

Rosemary Adamson, MB BS

Professor, Division of Pulmonary & Critical Care Medicine, UW

Attending Physician, Pulmonary & Critical Care Medicine, Seattle VA

What is your interest in PFTs?

1. I interpret spirometry
2. I have spirometry available in my office/clinic
3. I interpret full PFTs
4. I want to understand why the pulmonologists say the things they say
5. I want to keep up with changes to PFT interpretation

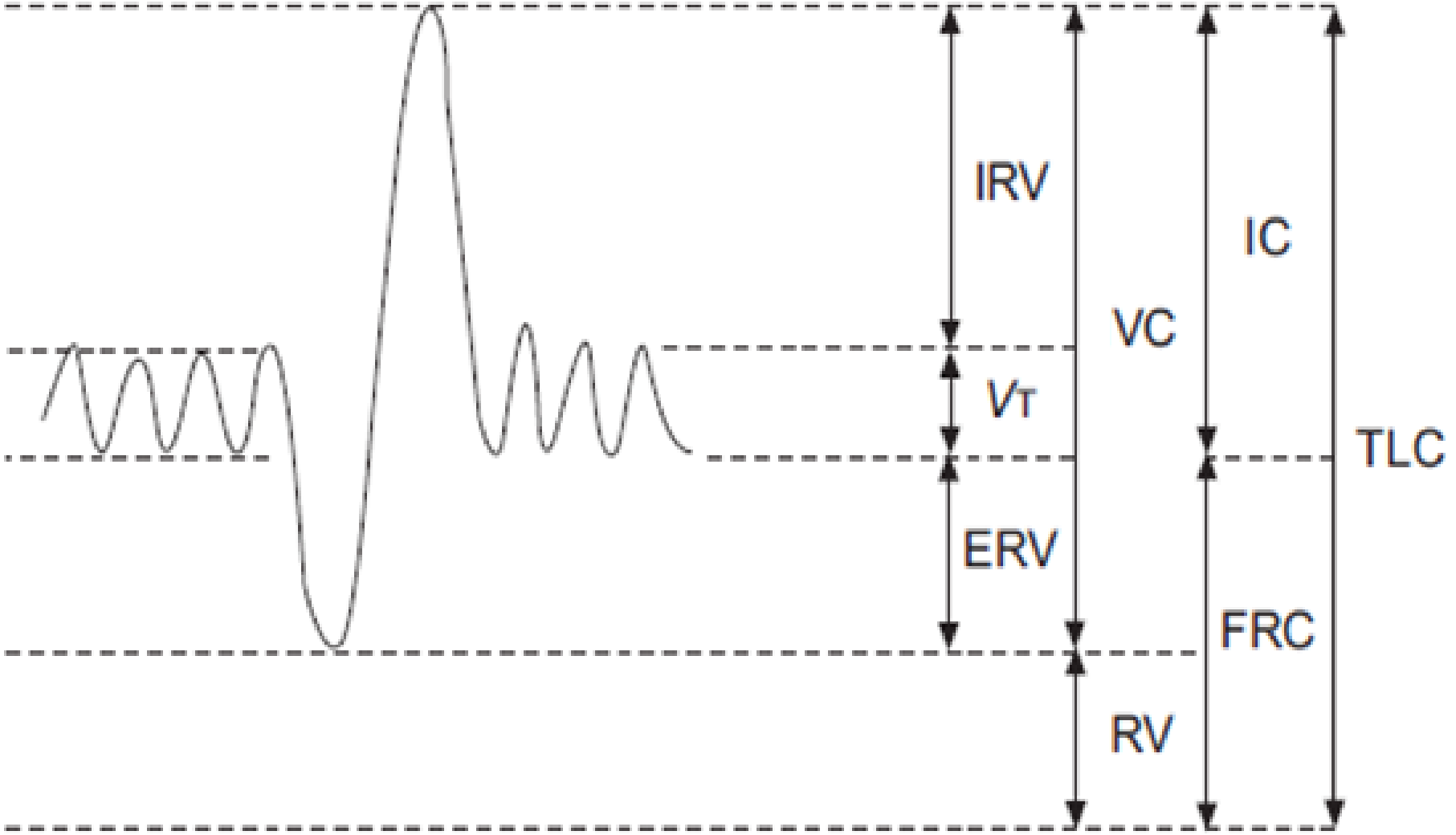
Learning Objectives:
By the end of this session, you will be able to:

- Interpret PFT results using z-scores
- Describe two methods to diagnose obstruction
- Interpret a significant bronchodilator response using the latest guidelines
- Diagnose pulmonary restriction and list at least three causes
- Recognize the non-specific pattern on PFTs
- Describe at least one benefit and one downside to using race-neutral equations for spirometry

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]

Eur Respir J. 2022;60:2101499.



Lung Volumes:

VT: Tidal Volume
VC: Vital Capacity
RV: Residual Volume
FRC: Functional Residual Capacity
TLC: Total Lung Capacity

IRV: Inspiratory Reserve Volume
ERV: Expiratory Reserve Volume
IC: Inspiratory Capacity

	Actual (L)	Predicted	% pred	Z score
FVC	4.17	4.08	102	0.18
FEV1	3.39	3.41	99	-0.06
FEV1/FVC	0.81	0.84		-0.46
SVC	4.25	4.27	99	-0.05
IC	2.60	2.77	94	-0.32
ERV	1.66	1.42	116	0.48
FRC	3.14	2.81	112	0.55
RV	1.48	1.28	115	0.43
TLC	5.74	5.57	103	0.25
DLCOuncorr	25.34	23.2	109	0.66
DLCOcorr	24.93	23.2	107	0.54

Review

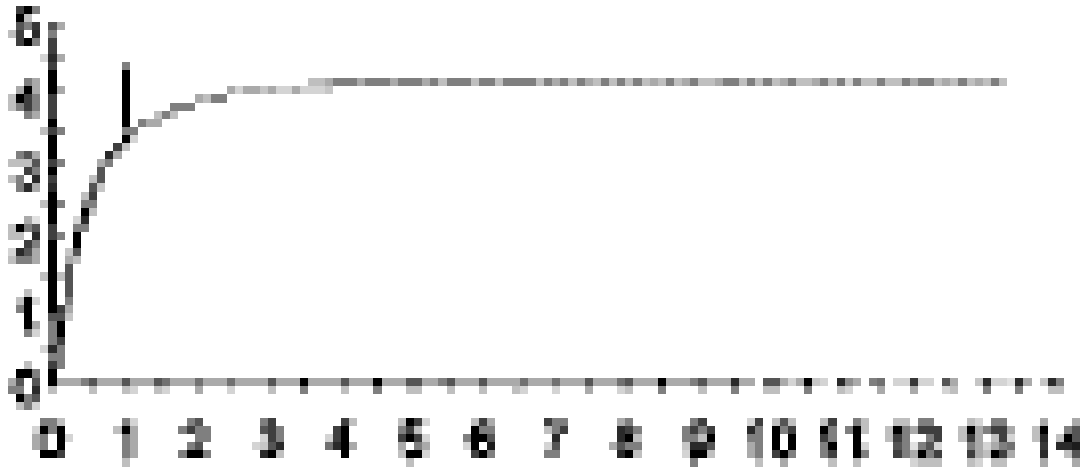
1)Graphics

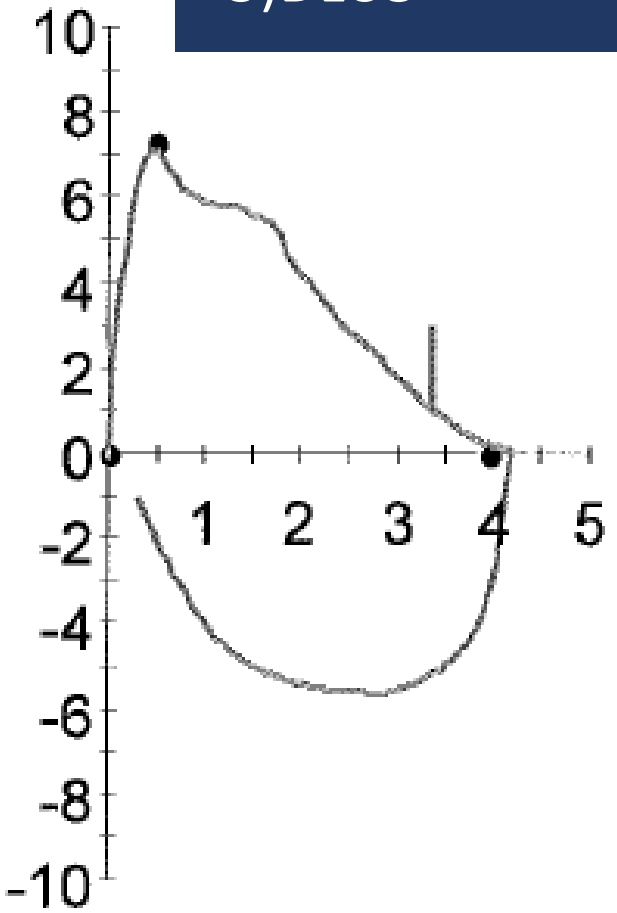
2)FEV1/FVC ratio

3)Forced spirometry (FEV1 & FVC)

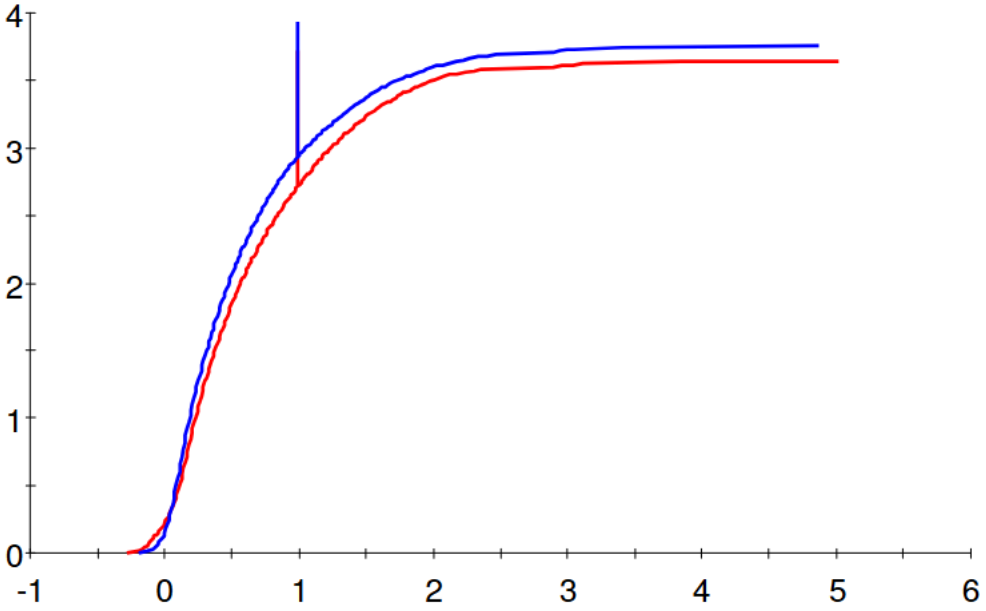
4)TLC

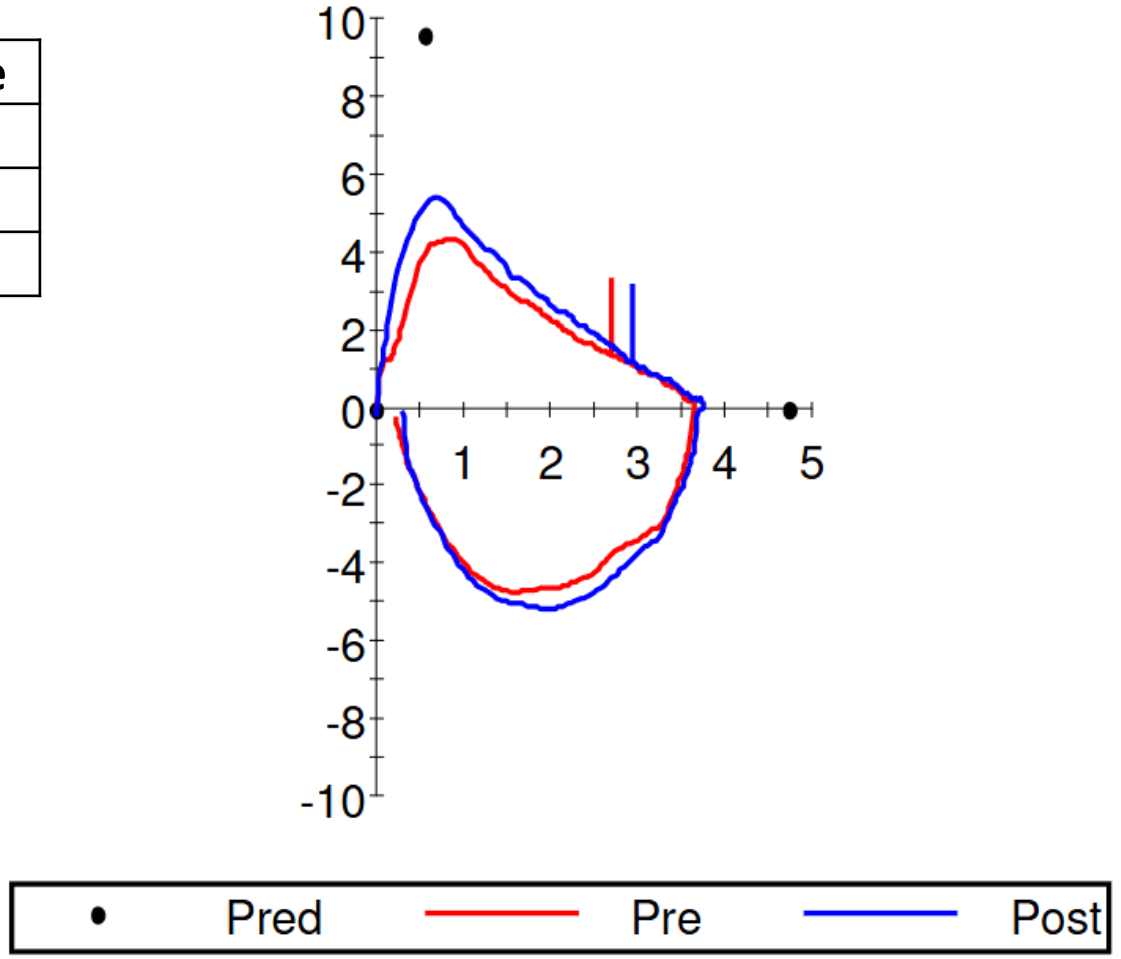
5)DLCO





	Actual (L)	Predicted	% pred	Z-score
FVC	3.66	4.75	77	-1.48
FEV1	2.73	3.53	77	-1.29
FEV1/FVC	0.74	0.75		-0.08

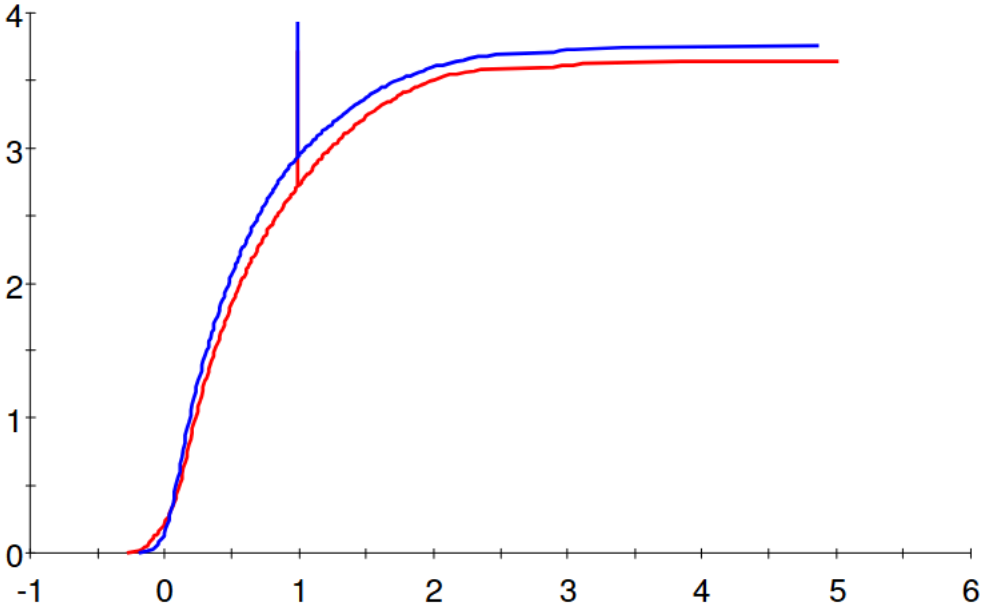


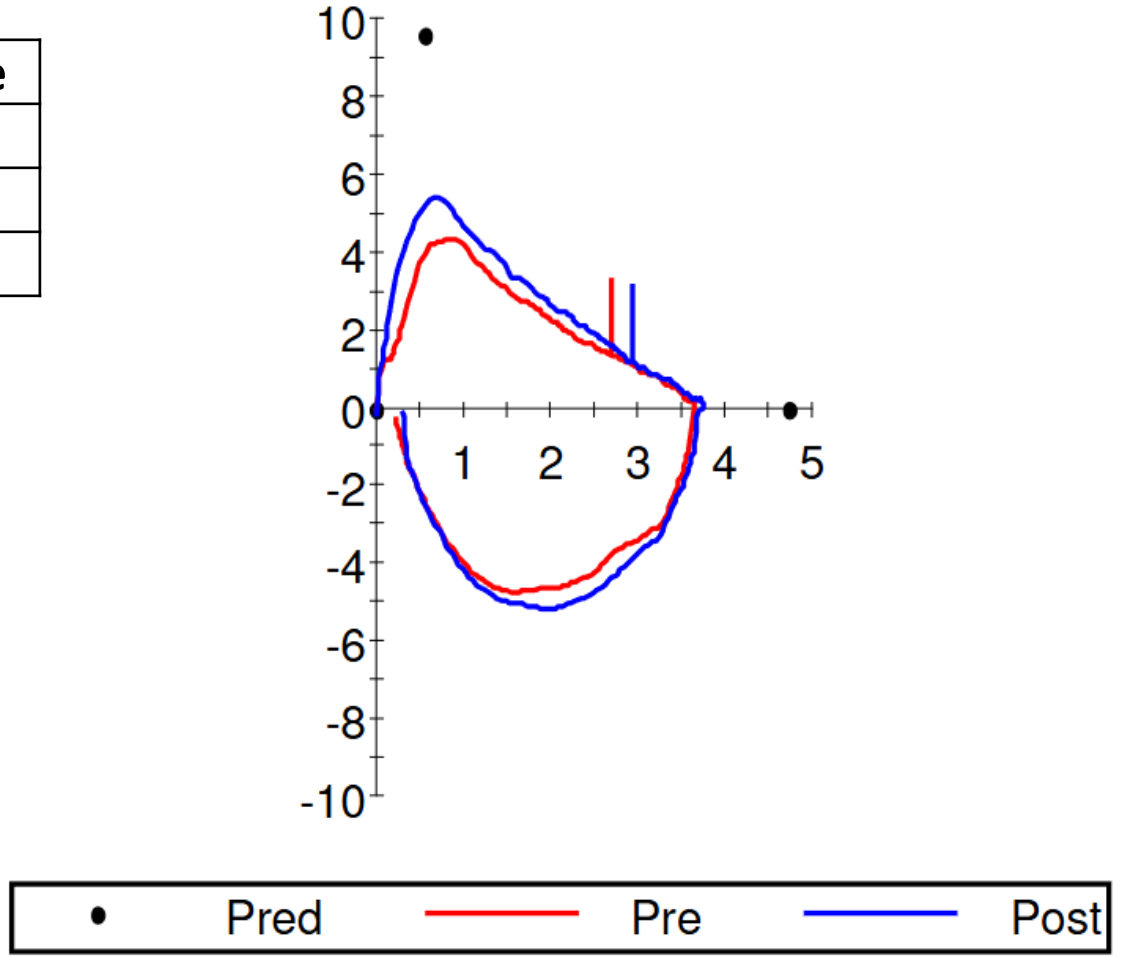


This spirometry shows

1. Airflow obstruction
2. Normal function
3. Possible restriction

	Actual (L)	Predicted	% pred	Z-score
FVC	3.66	4.75	77	-1.48
FEV1	2.73	3.53	77	-1.29
FEV1/FVC	0.74	0.75		-0.08

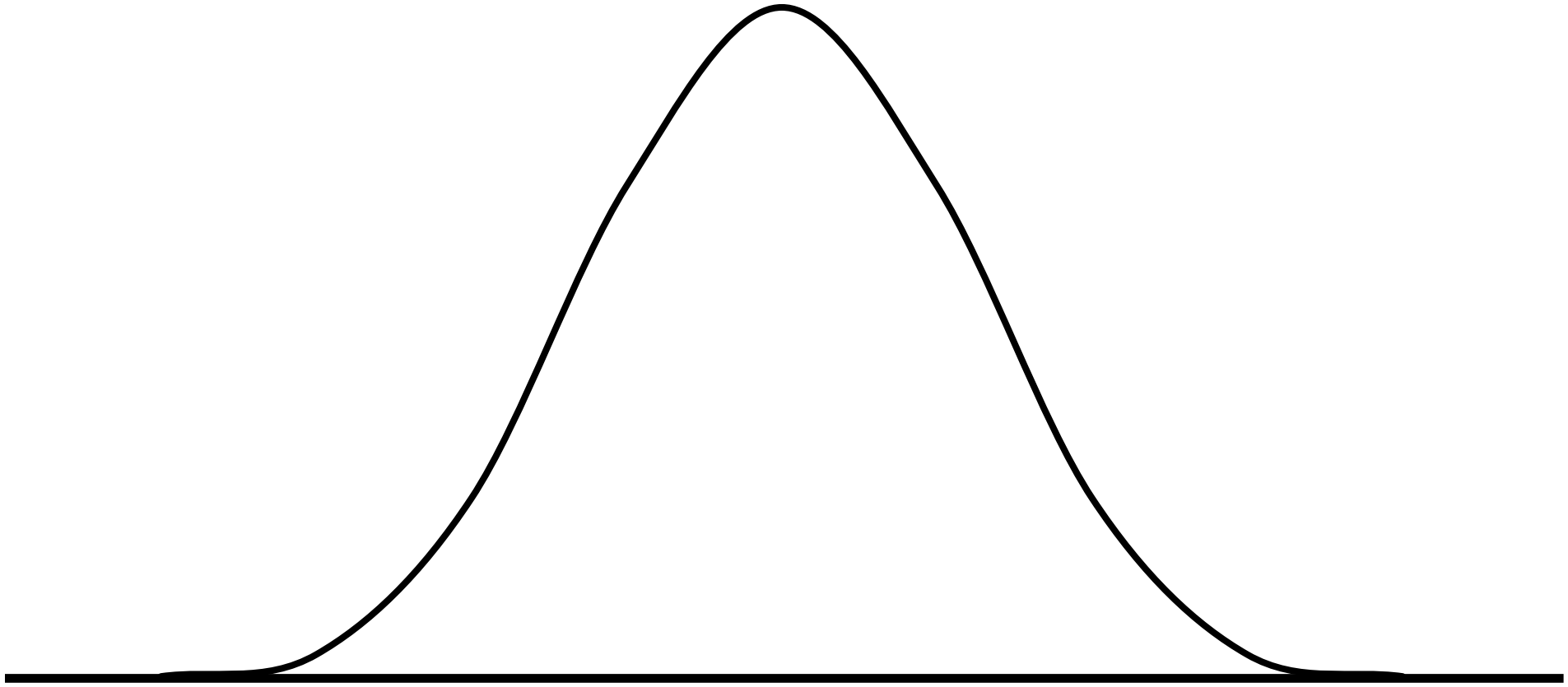




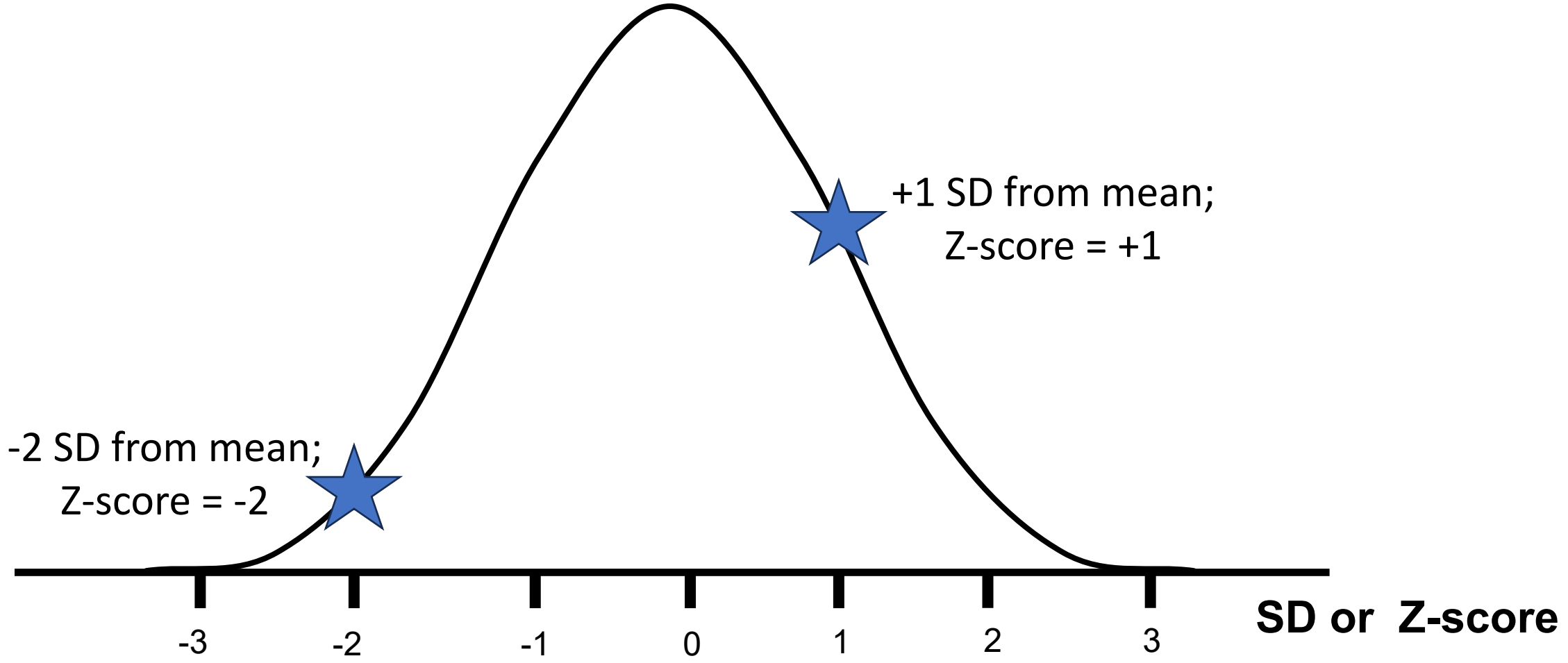
This spirometry shows

1. Airflow obstruction
2. Normal function
3. Possible restriction

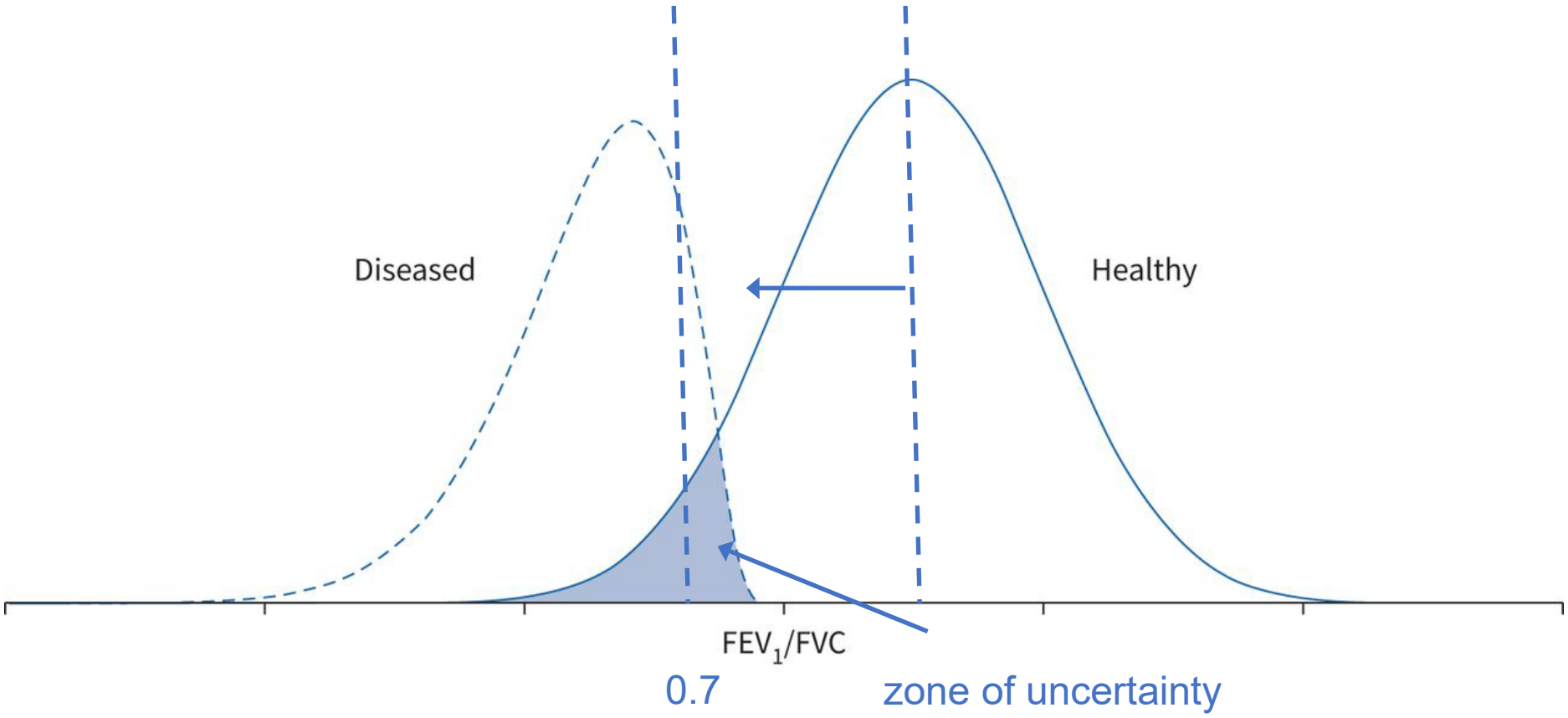
The lung function of a group of people of the same height, age & sex follows a normal distribution.



A z-score is a statistical measure of how many standard deviations a data point is from the mean of its dataset.

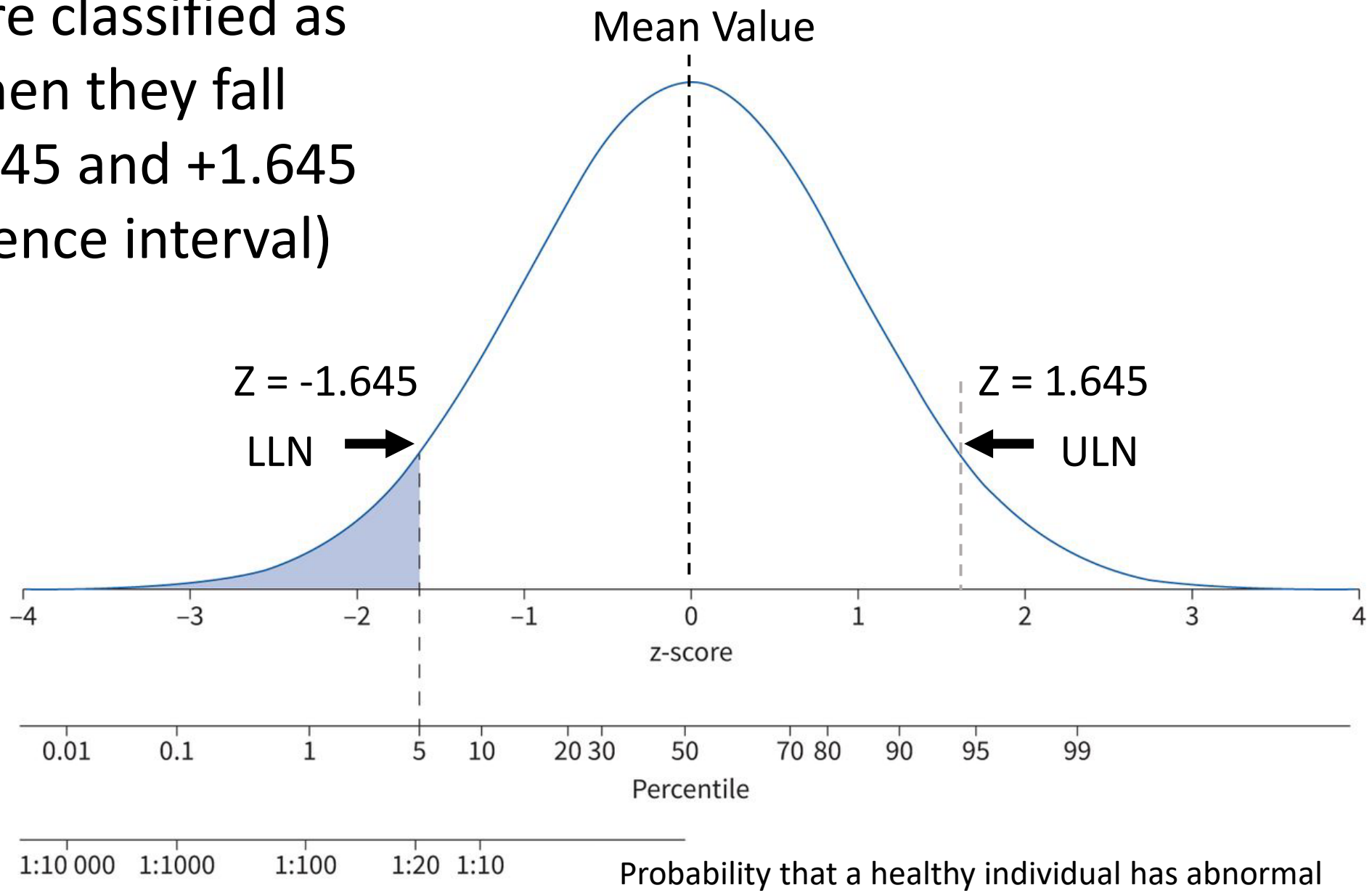


Our goal as clinicians is to identify individuals with abnormal values (disease).



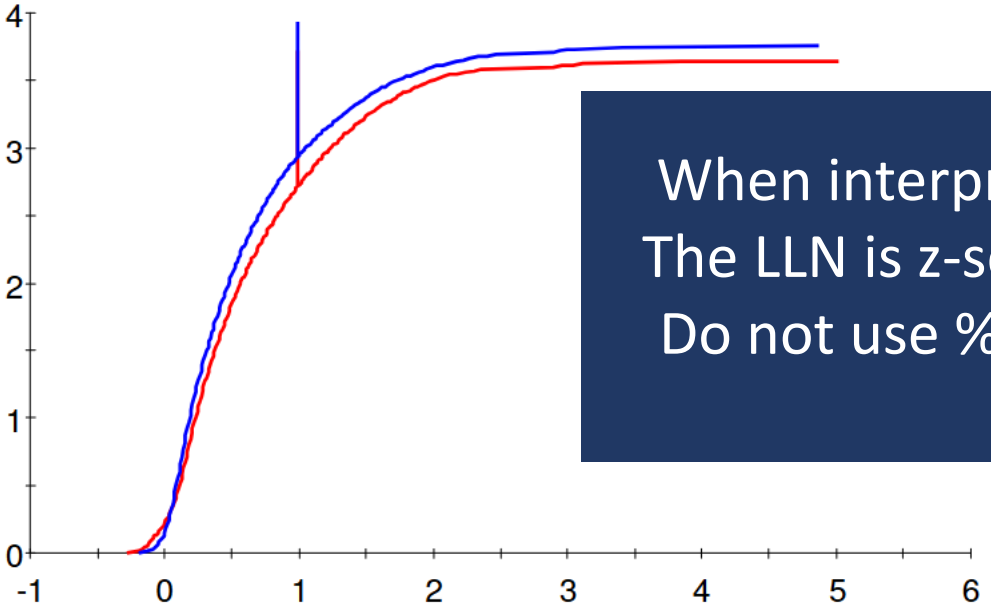
Stanojevic et al. Eur Respir J 2022;60:2101499

PFT values are classified as normal when they fall between -1.645 and +1.645 (90% confidence interval)

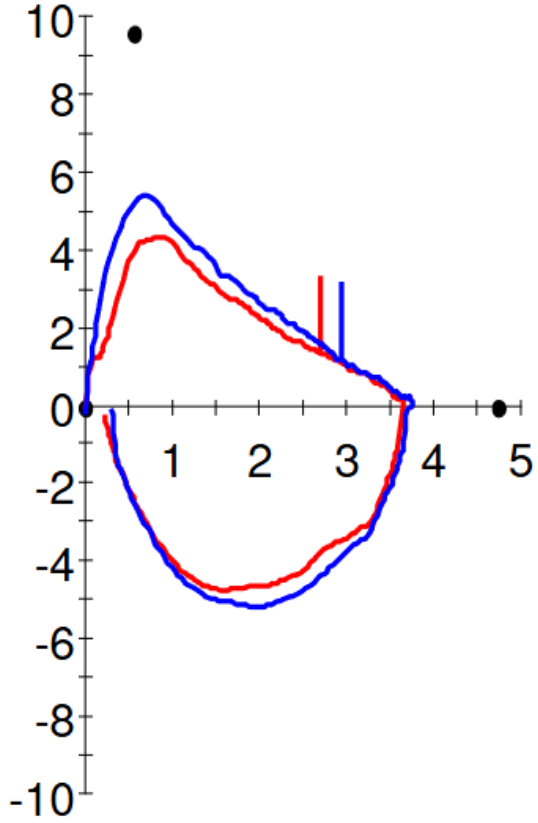


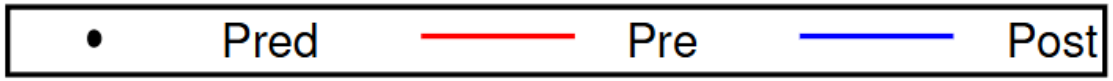
Stanojevic et al. Eur Respir J 2022;60:2101499

	Actual (L)	Predicted	% pred	Z-score
FVC	3.66	4.75	77	-1.48
FEV1	2.73	3.53	77	-1.29
FEV1/FVC	0.74	0.75		-0.08



When interpreting PFTs:
The LLN is z-score -1.645.
Do not use % predicted.

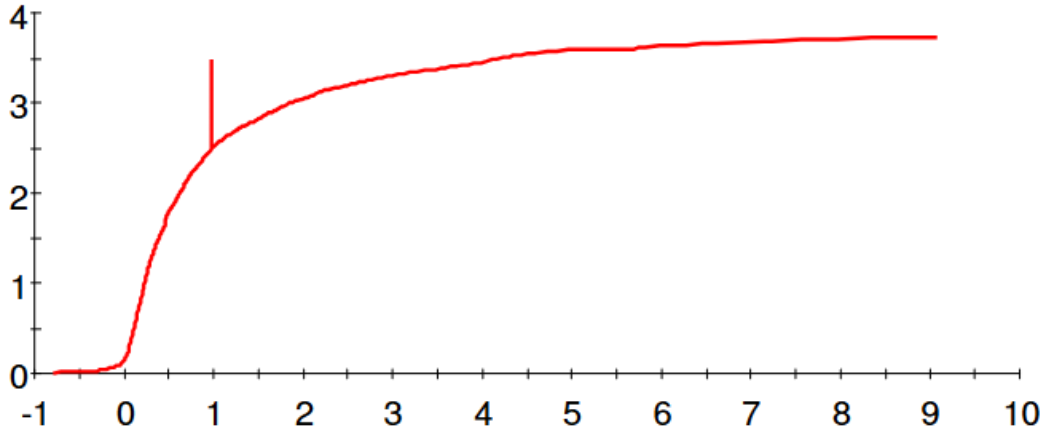


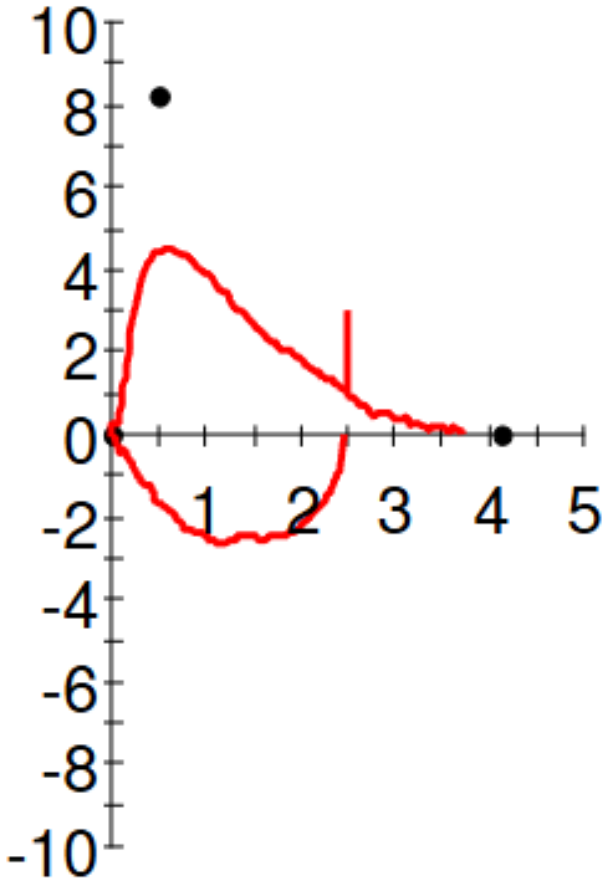


This spirometry shows

1. Airflow obstruction
2. Normal function
3. Possible restriction

	Actual (L)	Predicted	% pred	Z-score
FVC	3.85	4.12	93	-0.41
FEV1	2.51	3.05	82	-0.96
FEV1/FVC	0.65	0.75		-1.18

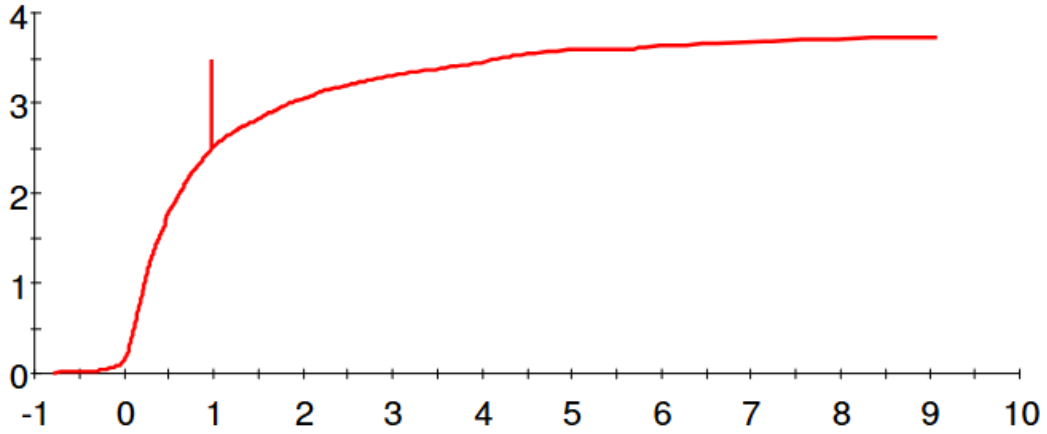


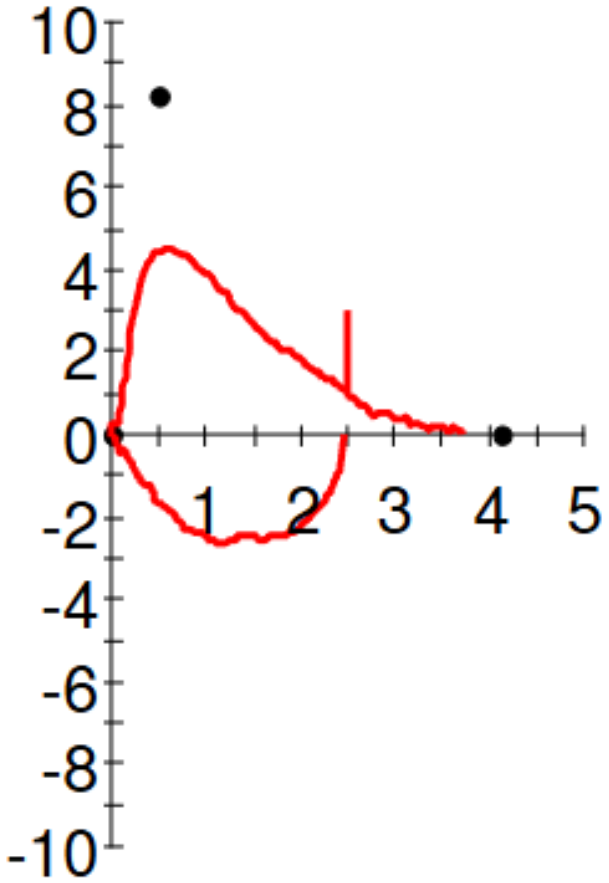


This spirometry shows

1. Airflow obstruction
2. Normal function
3. Possible restriction

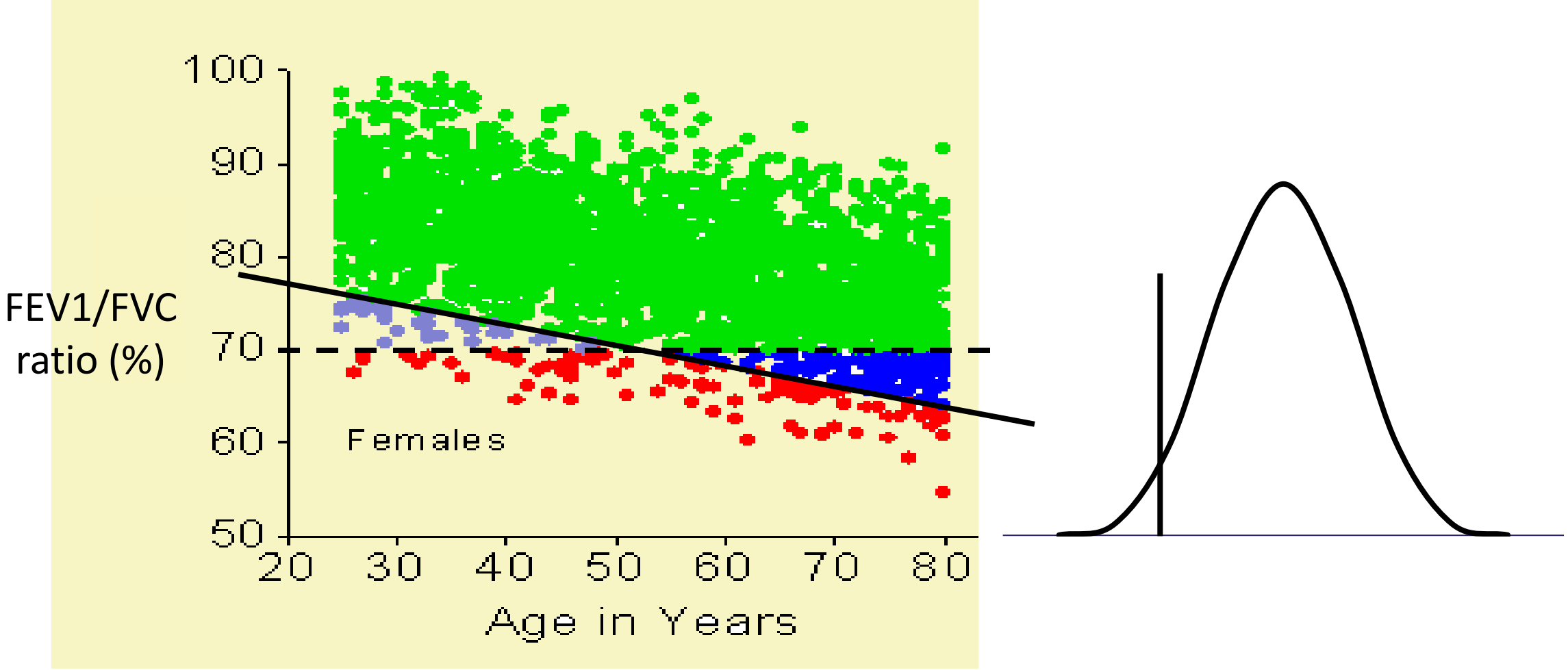
	Actual (L)	Predicted	% pred	Z-score
FVC	3.85	4.12	93	-0.41
FEV1	2.51	3.05	82	-0.96
FEV1/FVC	0.65	0.75		-1.18





This spirometry shows

1. Airflow obstruction
2. Normal function
3. Possible restriction



- Truly normal
- Within expected 5% of the total population (accepted false positives)
- False negatives: FEV1/FVC > 0.70, but below the LLN
- False positives: FEV1/FVC < 0.70, but above the LLN

Adapted from www.Spirxpert.com/controversies/controversy.html

	Actual (L)	Predicted	% pred	Z-score
FVC	3.85	4.12	93	-0.41
FEV1	2.51	3.05	82	-0.96
FEV1/VC	0.65	0.75		-1.18

GOLD diagnoses obstruction when FEV1/FVC ratio <0.7 but
this over-diagnoses obstruction in older &
under-diagnoses obstruction in younger people SO

Use FEV1/FVC < LLN (z-score of -1.645) to diagnose obstruction

This spirometry shows

1. Airflow obstruction
2. Normal function
3. Possible restriction

	pre-bronchodilator				post-bronchodilator		
	Actual (L)	Predicted	% pred	Z-score	Actual (L)	Z-score	% change
FVC	3.63	4.24	85	-1.18	4.01	-0.44	+10
FEV1	2.55	3.44	74	-1.98	2.83	-1.37	+11
FEV1/FVC	0.70	0.81	LLN 0.72	-1.84	0.71		

Does this spirometry show a significant bronchodilator response?

Yes or no

Criteria for significant bronchodilator response:

Post-bronchodilator (BD) change in FEV1 or FVC of >10% of predicted value:

$$\frac{\text{post-BD (L)} - \text{pre-BD (L)}}{\text{predicted value (L)}} \times 100$$

Stanojevic et al. Eur Respir J 2022;60:2101499

	pre-bronchodilator				post-bronchodilator		
	Actual (L)	Predicted	% pred	Z-score	Actual (L)	Z-score	% change
FVC	3.63	4.24	85	-1.18	4.01	-0.44	+10
FEV1	2.55	3.44	74	-1.98	2.83	-1.37	+11
FEV1/FVC	0.70	0.81	LLN 0.72	-1.84	0.71		

>10% change in FEV1 or FVC is a significant bronchodilator response (BDR)

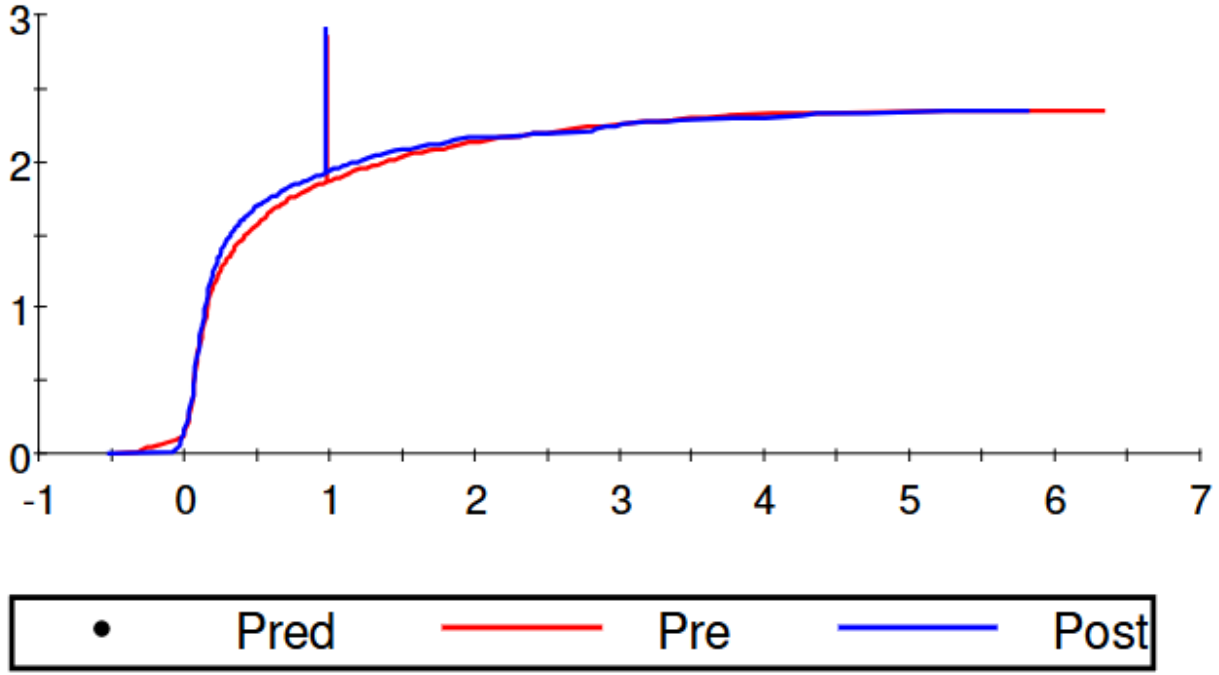
+ve BDR plus normalization of FEV1 and FVC is consistent with asthma

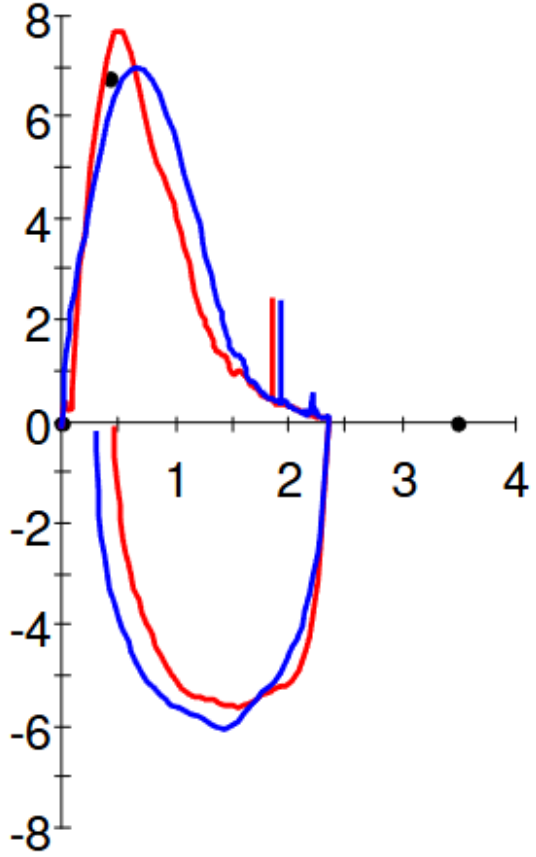
COPD diagnosis requires FIXED obstruction
i.e. FEV1 and FVC do not normalize after bronchodilator

	Actual (L)	Predicted	% pred	Z-score
FVC	2.35	3.47	67	-1.95
FEV1	1.87	2.58	72	-1.41
FEV1/FVC	0.80	0.75	LLN 0.61	0.00
TLC	4.28	5.76	60	-3.52
DLCO	14.6	29.3	49	-3.05

Which of the following diseases is this patient most likely to have:

1. ALS
2. COPD
3. IPF

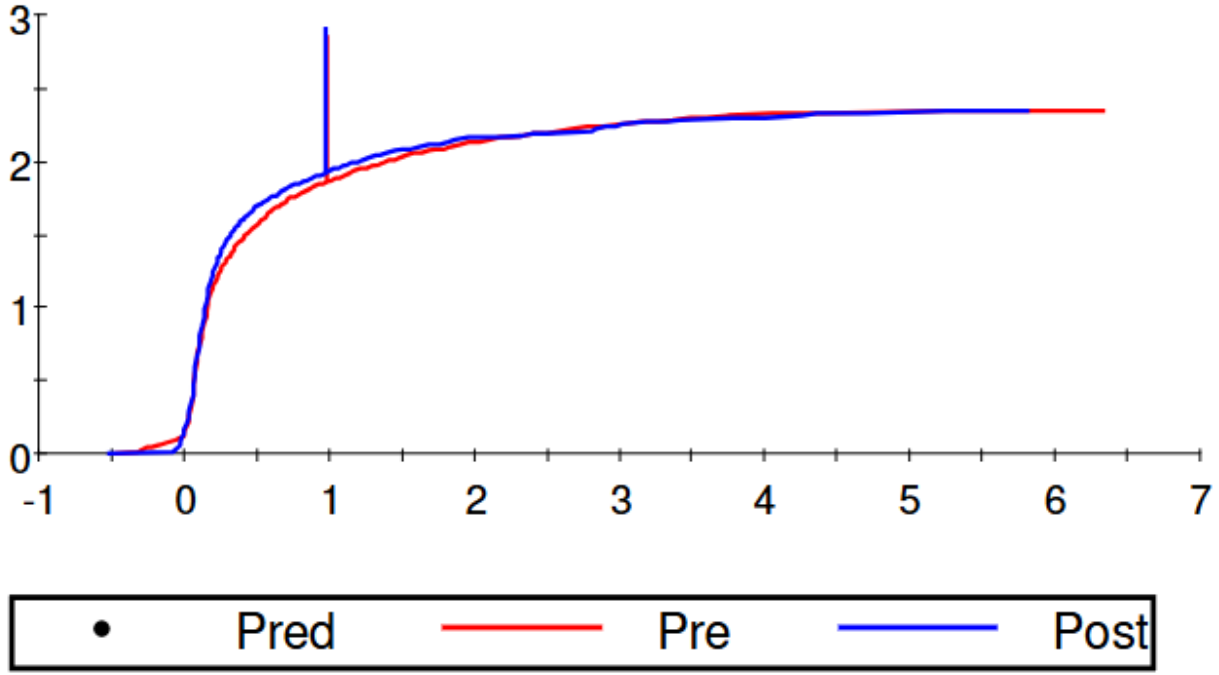


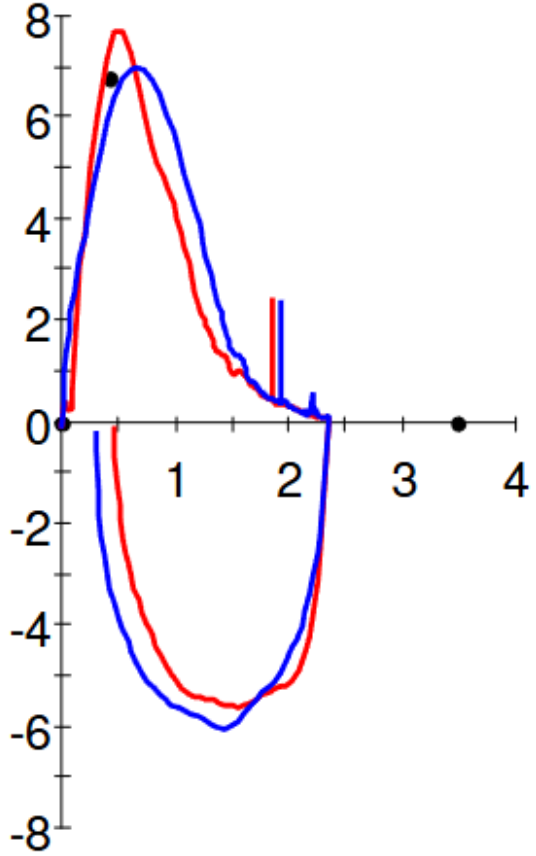


	Actual (L)	Predicted	% pred	Z-score
FVC	2.35	3.47	67	-1.95
FEV1	1.87	2.58	72	-1.41
FEV1/FVC	0.80	0.75	LLN 0.61	0.00
TLC	4.28	5.76	60	-3.52
DLCO	14.6	29.3	49	-3.05

Which of the following diseases is this patient most likely to have:

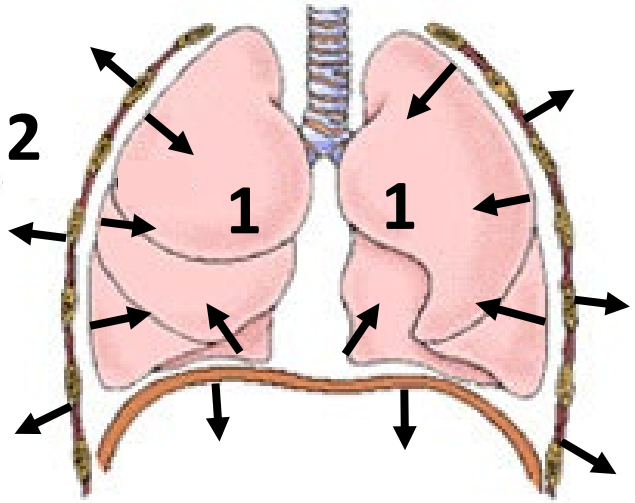
1. ALS
2. COPD
3. IPF





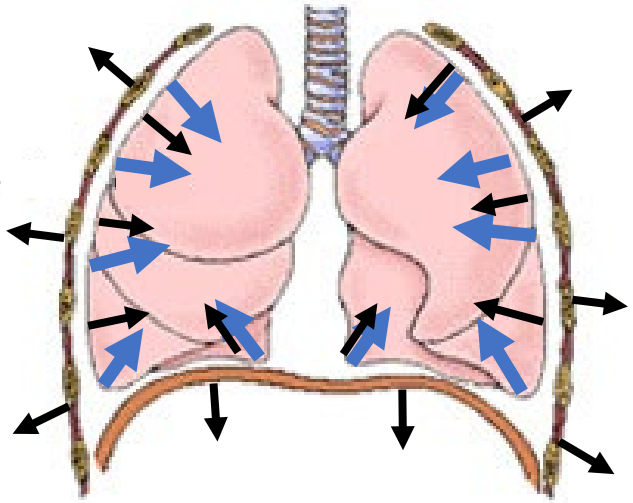
Lung volumes are created by the balance of 2 forces:

1. The inward recoil of the lung parenchyma
2. The outward recoil of the chest wall



When these forces are balanced, lung volumes are normal.

If one force increases or decreases, lung volumes change.



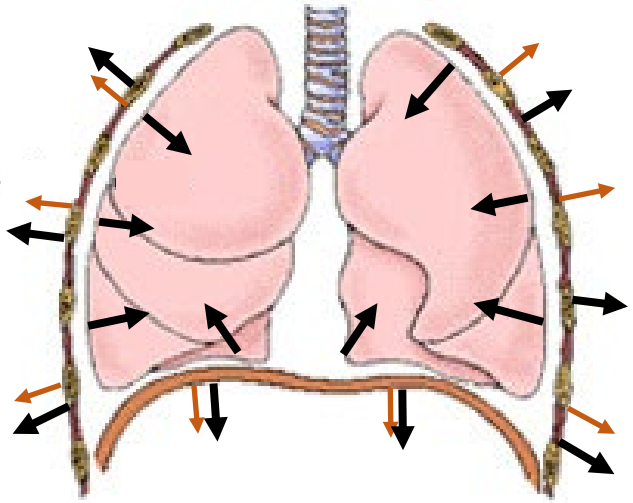
Restriction

TLC < LLN

Increased lung recoil

↓

Interstitial Lung Disease



Restriction

TLC < LLN

- Increased lung recoil
  - Diffuse Parenchymal Lung Disease
- Decreased chest wall recoil
  - Chest wall abnormality
  - Weakness

	Actual (L)	Predicted	% pred	Z-score
FVC	2.35	3.47	67	-1.95
FEV1	1.87	2.58	72	-1.41
FEV1/FVC	0.80	0.75	LLN 0.61	0.00
TLC	4.28	5.76	60	-3.52
DLCO	14.6	29.3	49	-3.05

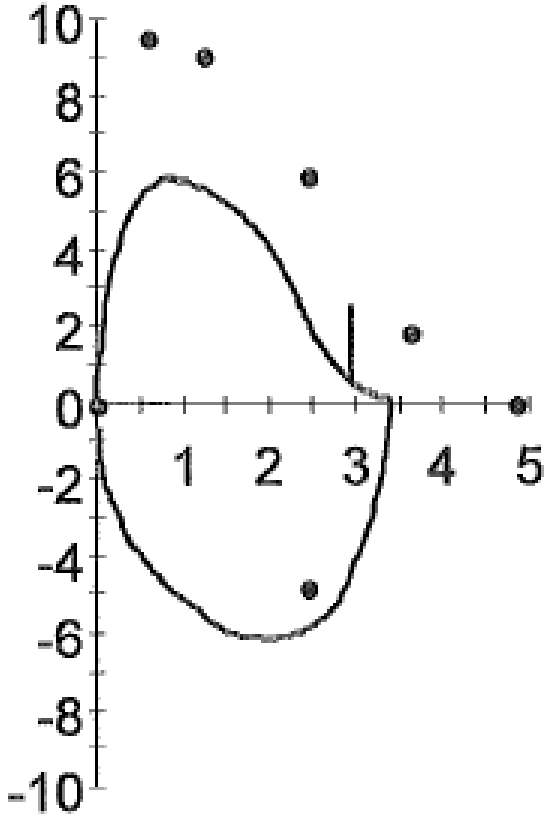
Which of the following diseases is this patient most likely to have:

1. ALS
2. COPD
3. IPF

Spirometry can only suggest restriction.
TLC < LLN defines restriction.

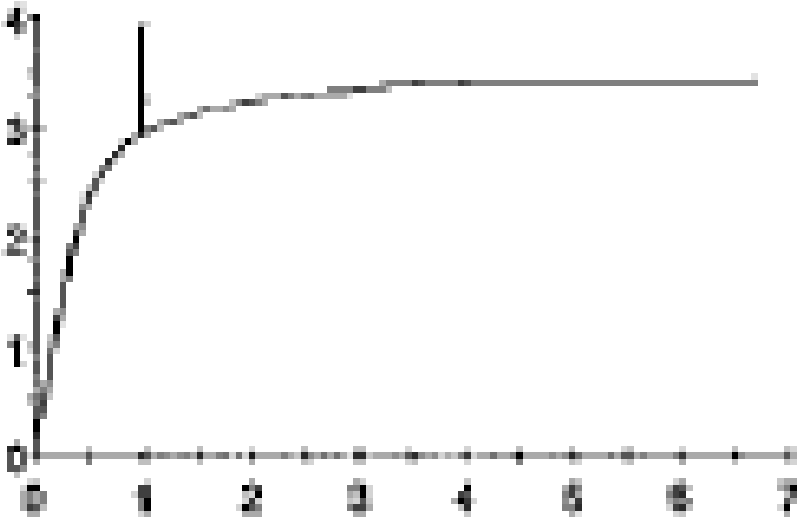
↓ TLC + ↓ DLCO suggests parenchymal lung disease (ILD).

	Actual	Predicted	% pred	Z-score
FVC (L)	3.40	4.84	70	-2.34
FEV1 (L)	2.94	3.83	76	-2.11
FEV1/FVC	0.86	0.79		1.01
TLC	5.84	6.98	83	-1.63
DLCO corr	29.26	35.60	82	-1.64



This spirometry shows

1. Airflow obstruction
2. Normal function
3. Possible restriction

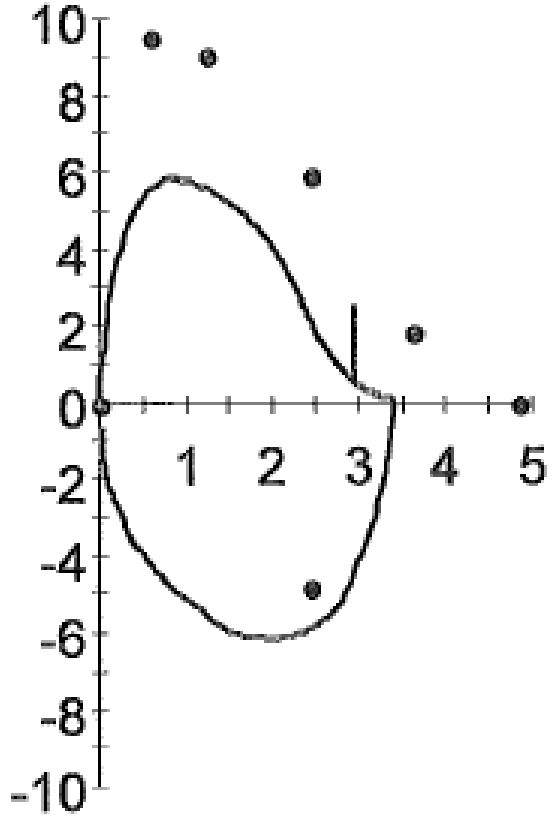


This TLC shows

1. Hyperinflation
2. Normal volume
3. Restriction

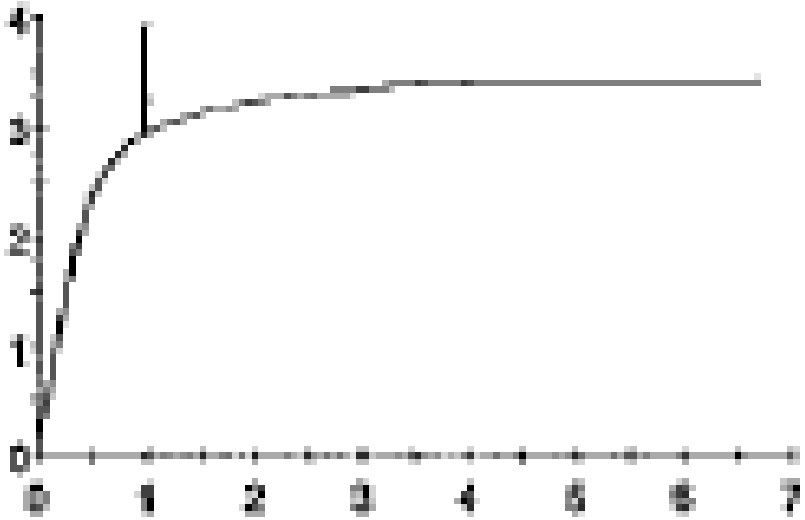
What is the name for this PFT pattern?

	Actual	Predicted	% pred	Z-score
FVC (L)	3.40	4.84	70	-2.34
FEV1 (L)	2.94	3.83	76	-2.11
FEV1/FVC	0.86	0.79		1.01
TLC	5.84	6.98	83	-1.63
DLCO corr	29.26	35.60	82	-1.64



This spirometry shows

1. Airflow obstruction
2. Normal function
3. Possible restriction



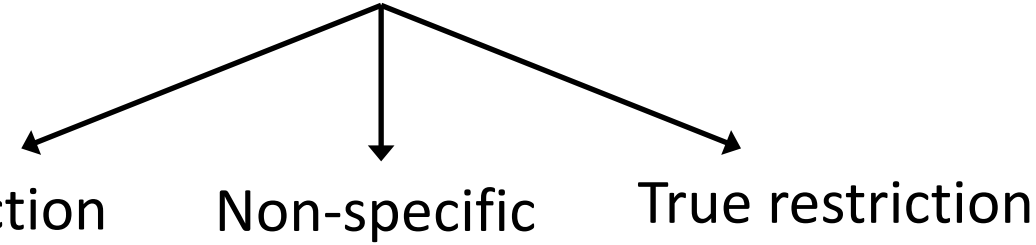
This TLC shows

1. Hyperinflation
2. Normal volume
3. Restriction

This is called the **non-specific pattern**.

The non-specific PFT pattern:

Spirometry suggests restriction, but TLC is normal



Other similar terms used if only spirometry is available:

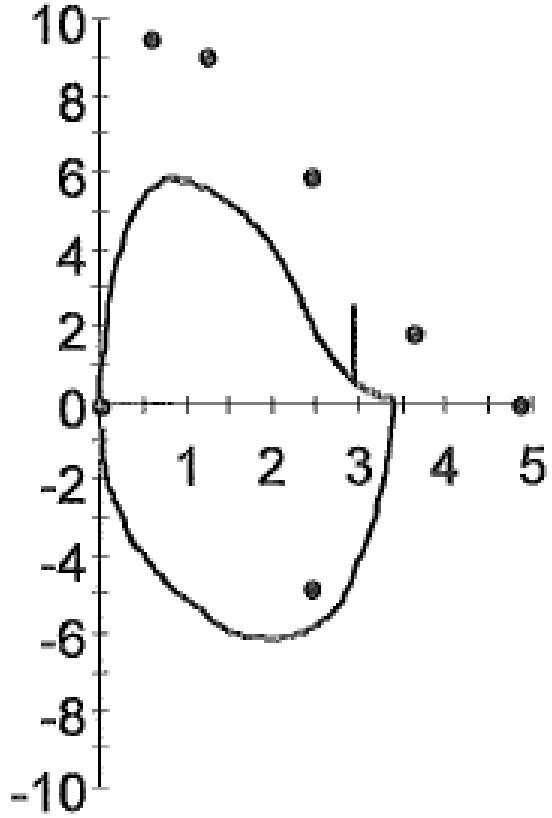
- Restrictive pattern spirometry
- PRISm: Preserved Ratio Impaired Spirometry

Associated with

- Higher mortality than normal PFTs
- A number of medical conditions (diabetes, metabolic syndrome)

Guerra et al. 2010 Morbidity and mortality associated with restrictive spirometric pattern : a longitudinal study. Thorax 65:499
Hyatt et al. 2009 Conditions associated with an abnormal nonspecific pattern of pulmonary function tests. Chest 135:419
Iyer et al. 2011 The Nonspecific Pulmonary Function test. Chest 139:878

	Actual	Predicted	% pred	Z-score
FVC (L)	3.40	4.84	70	-2.34
FEV1 (L)	2.94	3.83	76	-2.11
FEV1/FVC	0.86	0.79		1.01
TLC	5.84	6.98	83	-1.63
DLCO corr	29.26	35.60	82	-1.64



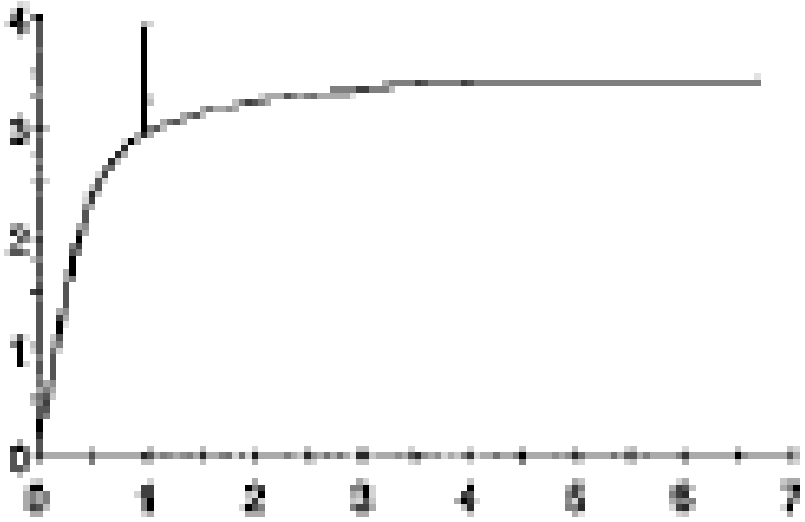
<u>The non-specific PFT pattern:</u>

Spirometry suggests restriction, but TLC is normal

Consider repeating PFTs in 1-3 years

This patient's BMI was 46

(Repeat PFT probably not necessary)



50-year-old man, 177cm tall.

	Actual	Predicted	% predicted	Z-score
FEV1	2.73	3.32	82	-1.20
FVC	3.38	4.17	81	-1.32
FEV1/FVC	0.81	0.77		0.17

How do you interpret this spirometry?

This spirometry shows

1. Airflow obstruction
2. Normal function
3. Possible restriction

50-year-old man, 177cm tall.

	Actual	Predicted	% predicted	Z-score
FEV1	2.73	3.32	82	-1.20
FVC	3.38	4.17	81	-1.32
FEV1/FVC	0.81	0.77		0.17

How do you interpret this spirometry?

This spirometry shows

1. Airflow obstruction
2. Normal function
3. Possible restriction

50-year-old man, 177cm tall, identifies as Black.

		Using GLI 2012 African American (race-specific)			Using GLI 2022 Global (race-neutral)		
	Actual	Predicted	% predicted	Z-score	Predicted	% predicted	Z-score
FEV1	2.73	3.32	82	-1.20	3.68	74	-1.72
FVC	3.38	4.17	81	-1.32	4.60	73	-1.83
FEV1/FVC	0.81	0.77		0.17	0.80		0.21

How do you interpret the spirometry using the race-neutral equation?

1. Airflow obstruction
2. Normal function
3. Possible restriction

50-year-old man, 177cm tall, identifies as Black.

		Using GLI 2012 African American (race-specific)			Using GLI 2022 Global (race-neutral)		
	Actual	Predicted	% predicted	Z-score	Predicted	% predicted	Z-score
FEV1	2.73	3.32	82	-1.20	3.68	74	-1.72
FVC	3.38	4.17	81	-1.32	4.60	73	-1.83
FEV1/FVC	0.81	0.77		0.17	0.80		0.21

Using GLI 2022 Global equations, the spirometry shows

1. Airflow obstruction
2. Normal function
3. Possible restriction

50-year-old man, 177cm tall, identifies as Black.

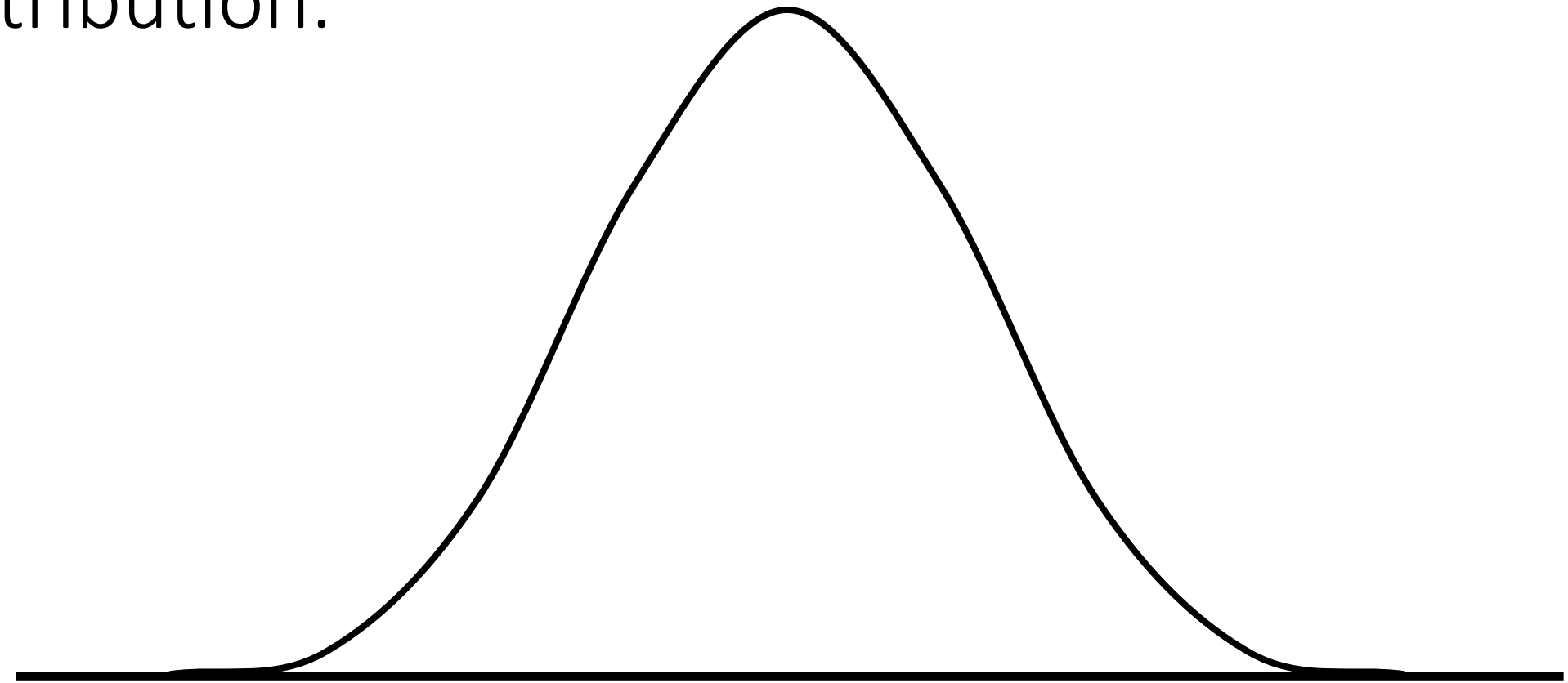
		Using GLI 2012 African American (race-specific)			Using GLI 2022 Global (race-neutral)		
	Actual	Predicted	% predicted	Z-score	Predicted	% predicted	Z-score
FEV1	2.73	3.32	82	-1.20	3.68	74	-1.72
FVC	3.38	4.17	81	-1.32	4.60	73	-1.83
FEV1/FVC	0.81	0.77		0.17	0.80		0.21

Using GLI 2012 African American equations, the spirometry shows normal function

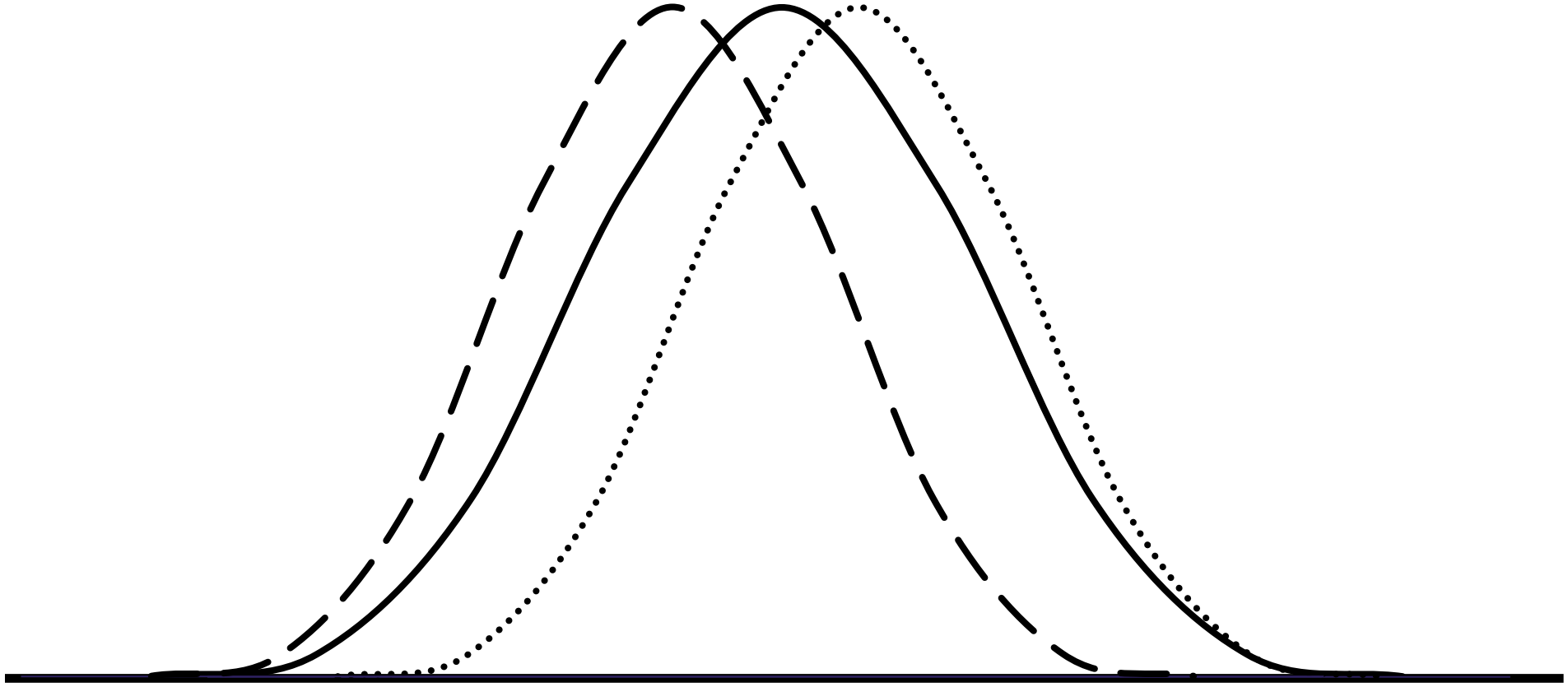
BUT

Using GLI 2022 Global equations, the spirometry shows possible restriction

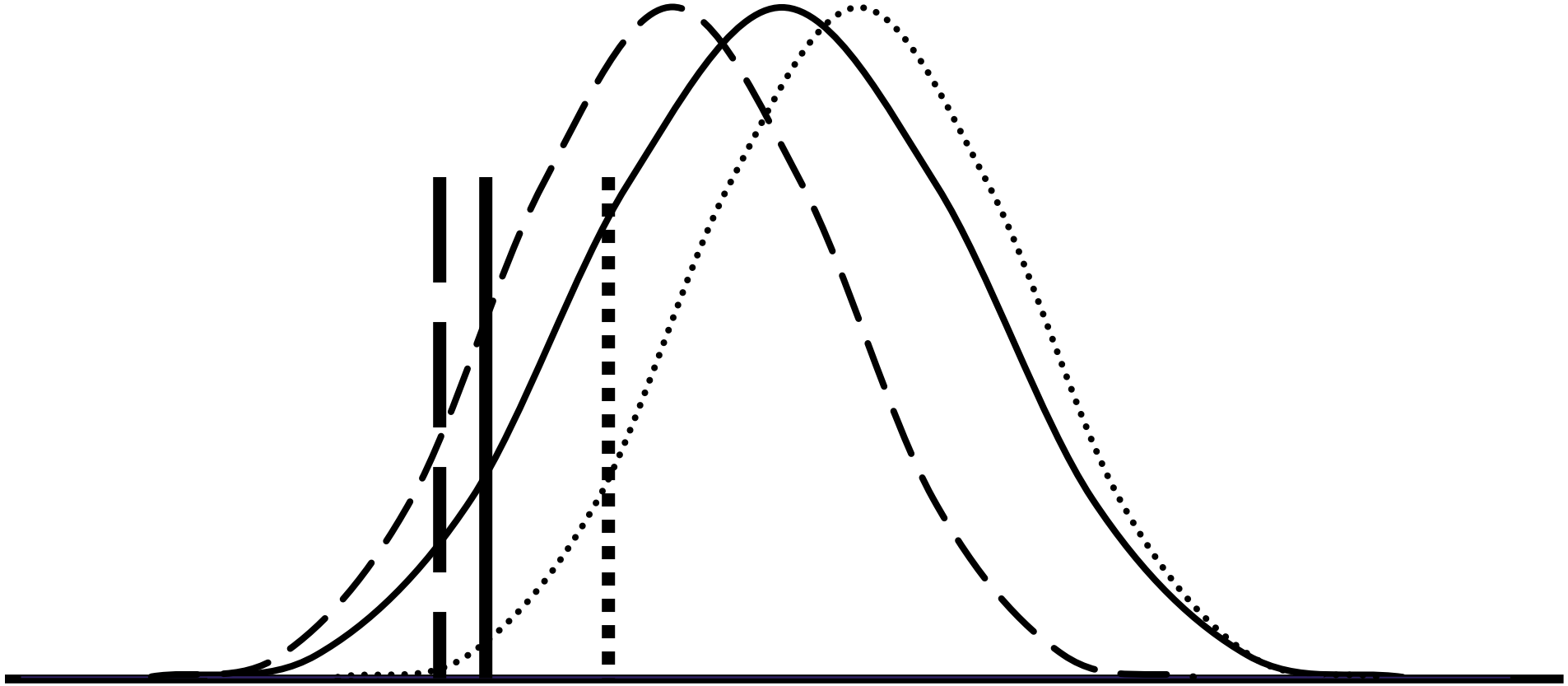
PFT predicted values are generated by equations developed from reference populations matched for height, age, sex, which results in a normal distribution.



Historically race has also been included, resulting in different equations with different predicted values for people of different races.



Historically race has also been included, resulting in different equations with different predicted values for people of different races – and different LLNs.



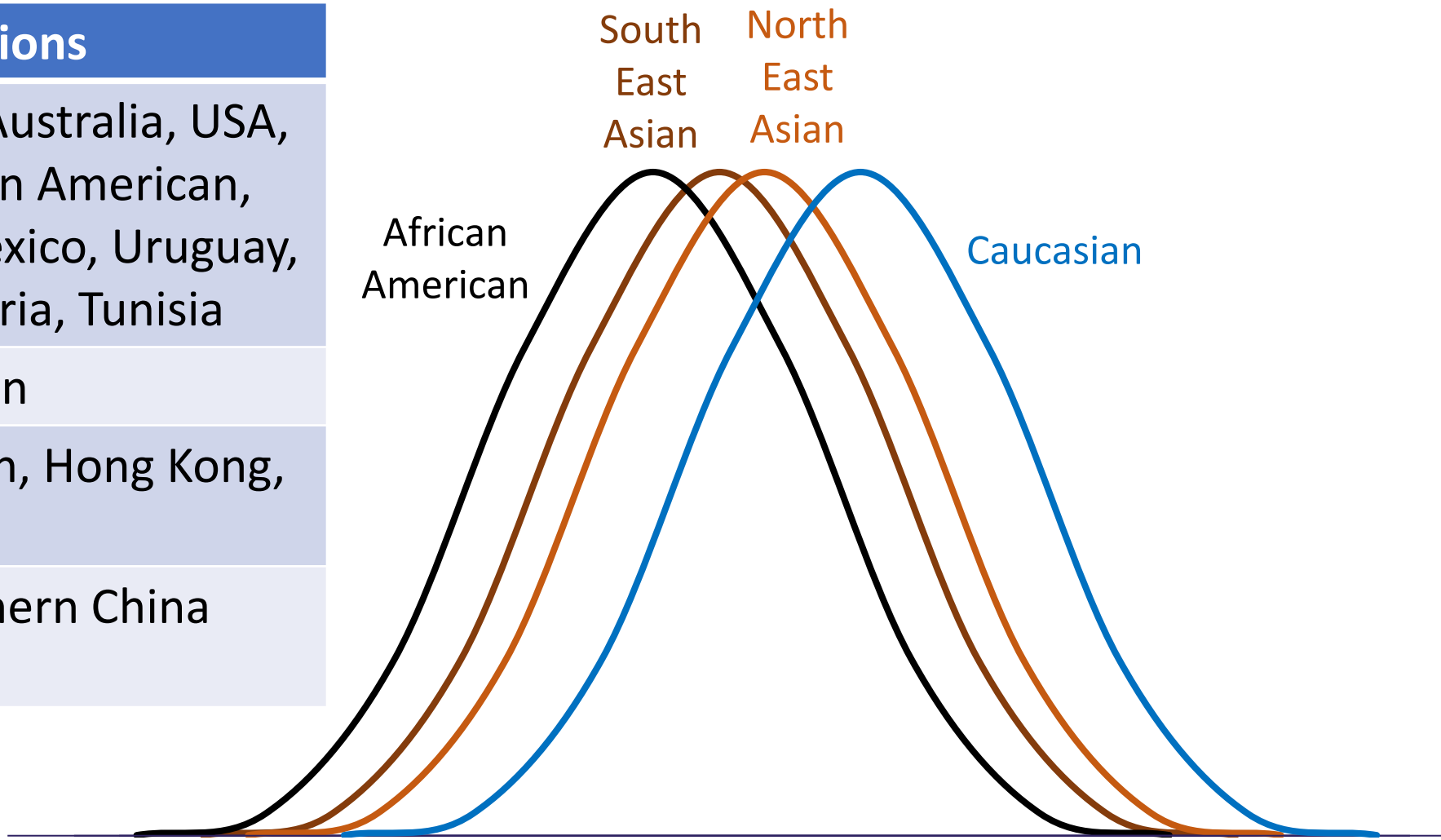
GLI (Global Lung Function Initiative) 2012: largest, most recent attempt to standardize equations

- Data initially from 33 countries
  - No representation from Malaysia, Indonesia and sub-Saharan Africa
  - Poor representation from South America
  - Indian subcontinent: 5 datasets (N=5,477) but poor concordance therefore reference equations could not be derived
- Data analyzed from 31,856 males and 42,331 females (aged 2.5-95y)
  - African American: 3,545
  - Caucasian: 57,395
  - North East Asian: 4,992
  - South East Asian: 8,255

Quanjer et al. Eur Repir J 2012;40:1324-1343

GLI 2012 found 4 groups by statistical analysis

Group	Countries / Regions
Caucasian	Europe, Israel, Australia, USA, Canada, Mexican American, Brazil, Chile, Mexico, Uruguay, Venezuela, Algeria, Tunisia
Black	African American
South East Asian	Thailand, Taiwan, Hong Kong, southern China
North East Asian	Korea and northern China



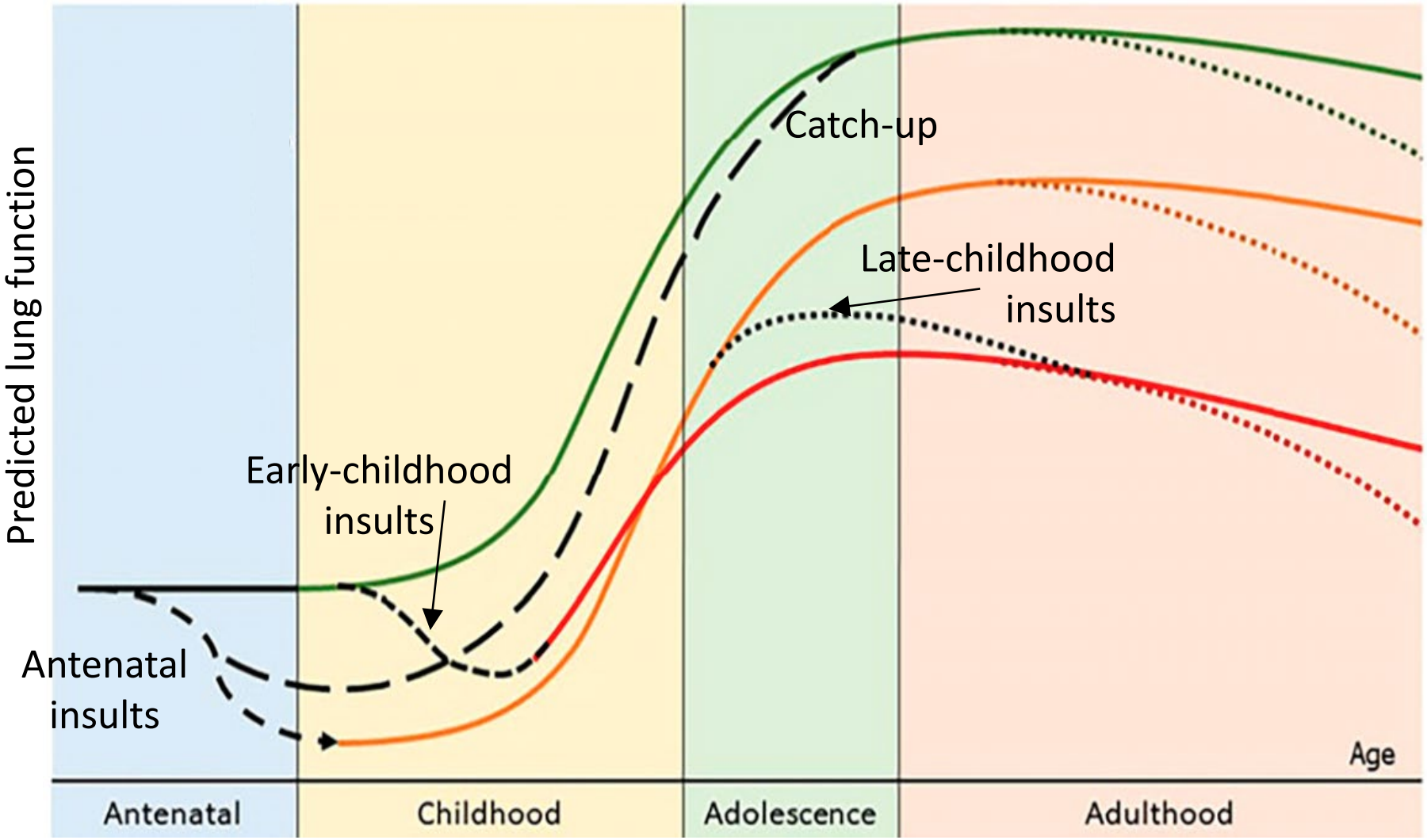
Quanjer et al. Eur Repir J 2012;40:1324-1343

Exposures that are associated with reduced lung function include:

- Childhood respiratory infections[1]
- Air quality (smoke exposure, pollution) [2,3]
- Socioeconomic background[4,5]
- Early-life nutrition[6]
- Pre-natal exposures[7]

1. Tennant PW. Chest. 2010;137(1):146-155.
2. Belgrave DCM. Lancet Respir Med. 2018;6(7):526-534.
3. Gauderman WJ. Eur Respir J. 2021;57(3):2001600
4. Rocha V. Eur Respir J. 2021;57(3):2001600
5. Hegewald MJ, Crapo RO. Chest. 2007;132(5):1608-1614.
6. Aggarwal M. Am J Respir Crit Care Med. 2021;204(9):1109-1111.
7. Lee AG. Am J Respir Crit Care Med. 2019;199(6):738-746.

Influence of environmental exposures on lung growth and aging



Normal

Normal with accelerated aging

Persistently reduced

Persistently reduced with accelerated aging

Increased obstruction during growth

Increased obstruction during growth with accelerated aging

Bhakta, Bime, et al. Am J Respir Crit Care Med 2023;207(8):978-995

Accepting “race” as the explanation for differences in lung function between racial groups avoids analyzing the true causes

- Childhood respiratory infections[1]
- Air quality (smoke exposure, pollution) [2,3]
- Socioeconomic background[4,5]
- Early-life nutrition[6]
- Pre-natal exposures[7]

1. Tennant PW. Chest. 2010;137(1):146-155.
2. Belgrave DCM. Lancet Respir Med. 2018;6(7):526-534.
3. Gauderman WJ. Eur Respir J. 2021;57(3):2001600
4. Rocha V. Eur Respir J. 2021;57(3):2001600
5. Hegewald MJ, Crapo RO. Chest. 2007;132(5):1608-1614.
6. Aggarwal M. Am J Respir Crit Care Med. 2021;204(9):1109-1111.
7. Lee AG. Am J Respir Crit Care Med. 2019;199(6):738-746.

Alternatives to race-specific equations: Race-neutral equations

GLI 2012 other

- Used all included GLI 2012 data
- Groups with few observations contribute less to predicted values

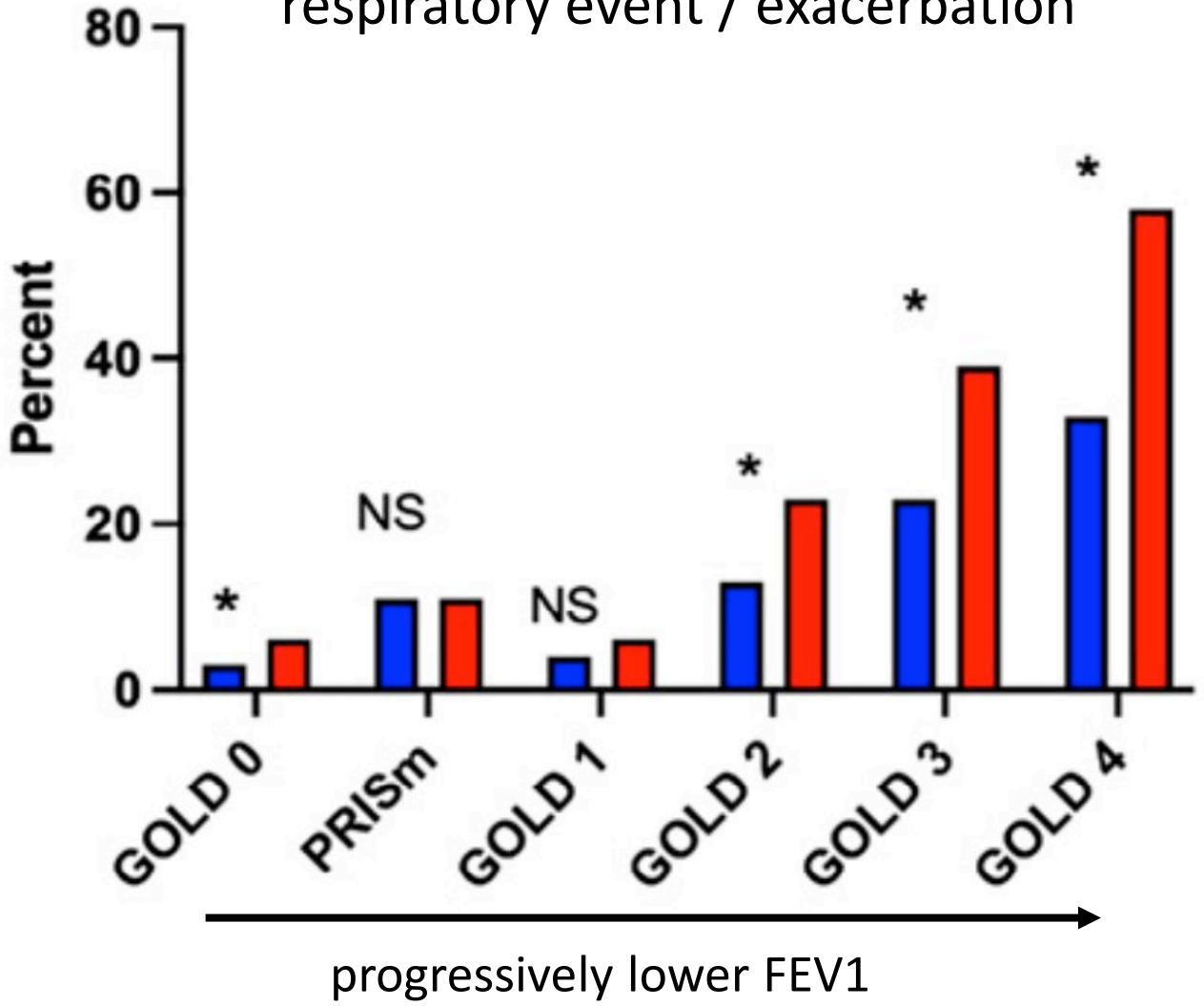
GLI 2022 global

- Weighted the GLI 2012 data
- Inverse probability weighting for racial/ethnic groups in GLI 2012 data i.e., 1/total sample in given sex
- All groups contribute equally to predicted values

Bowerman C, et al. A Race-neutral Approach to the Interpretation of Lung Function Measurements. *Am J Respir Crit Care Med.* 2023; 207: 768-774.

Black Americans have more symptoms than non-Hispanic White Americans with the same severity of COPD using race-specific equations

Percent people in each group with severe respiratory event / exacerbation



*p<0.0001

NS = non-significant

Non-Hispanic White

African American

Regan et al. *Am J Respir Crit Care* 2023:209:59

Race-neutral equations (GLI 2012 other) predict mortality and hospitalizations as well as race-specific equations

Elmaleh-Sachs et al. *Am J Respir Crit Care Med* 2022;205:700

Race-*specific* equations, may disadvantage Black & Asian people when evaluating for restriction or therapies prescribed for reduced lung function

Clinical Context	Black Reference Equation	White Reference Equation	GLI Global Reference Equation
Evaluation for ILD Male, 54yo, 190cm tall, FVC 3.9L	81%	68%	74%
Evaluation for lung transplantation Male, 60yo, 176cm tall, FVC 1.6L	42%	35%	38%

Adapted from Bhakta, Bime, et al. Am J Respir Crit Care Med 2023;207(8):978-995

Race-*specific* equations, may disadvantage Black & Asian people when evaluating for restriction or therapies prescribed for reduced lung function

Clinical Context	Black Reference Equation	White Reference Equation	GLI Global Reference Equation
Evaluation for ILD Male, 54yo, 190cm tall, FVC 3.9L	81%	68%	74%
Evaluation for lung transplantation Male, 60yo, 176cm tall, FVC 1.6L	42%	35%	38%

Cut-point: FVC < 40% predicted

Adapted from Bhakta, Bime, et al. Am J Respir Crit Care Med 2023;207(8):978-995

Race-*neutral* equations, may disadvantage White people when evaluating for therapies prescribed for reduced lung function

Clinical Context	Black Reference Equation	White Reference Equation	GLI Global Reference Equation
Evaluation for non-invasive ventilatory support for weakness Male, 60yo, 176cm tall, FVC 2.2L	57%	49%	53%
	Cut-point: FVC < 50% predicted		

Adapted from Bhakta, Bime, et al. Am J Respir Crit Care Med 2023;207(8):978-995

50-year-old man, 177cm tall, identifies as Black.

		Using GLI 2012 African American (race-specific)			Using GLI 2022 Global (race-neutral)		
	Actual	Predicted	% predicted	Z-score	Predicted	% predicted	Z-score
FEV1	2.73	3.32	82	-1.20	3.68	74	-1.72
FVC	3.38	4.17	81	-1.32	4.60	73	-1.83
FEV1/FVC	0.81	0.77		0.17	0.80		0.21

PFT reports only use one equation, but do list this at the top of the report.
This only applies to spirometry
(there aren't race-specific equations for volumes & DLCO)

If curious, you can use online calculator to see the effect of different equations:
https://gli-calculator.ersnet.org/

Take Home Points

- Use z-scores to interpret PFTs (normal is from 1.645 to -1.645)
- FEV1/FVC < LLN is more specific for obstruction than using FEV1/FVC < 0.7 (fixed ratio)
- >10% change in FEV1 or FVC post-BD, compared to predicted, is significant
- Restriction is defined by TLC<LLN
- Restriction is caused by disorders of lung parenchyma, chest wall and muscle strength
- The non-specific pattern is when spirometry suggests restriction, but TLC is within normal limits
- Race neutral equations make sense but may not always improve equity

Division of Pulmonary, Critical Care
& Sleep Medicine
University of Washington

Thank you.
Questions?

Rosemary Adamson, MB BS
adamsonr@uw.edu