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UWTSD Sport and Exercise Science Physiological Testing Protocols

Pulmonary Function

Taken From:

Lab 5

**Housh, T.J., Cramer, J.T., Weir, J.P., Beck, T.W. and
Johnson, G.O. (2016). Laboratory manual for
Exercise Physiology, Exercise Testing and Physical
Activity. London: Routledge.**

BACKGROUND

The pulmonary system includes the nasal cavity, pharynx, epiglottis, larynx, trachea, bronchus, lungs, and alveoli. The primary functions of the pulmonary system are to participate in the processes of external and internal respiration.^{7,13} External respiration refers to the movement of oxygen and other gases from the outside environment into and out of the lungs, while internal respiration refers to the exchange of gases between the alveoli within the lungs and the blood cells.^{7,13}

Two types of tests, static and dynamic, can be used to assess pulmonary function. Static tests measure variables such as vital capacity (VC), residual volume (RV), and total lung capacity (TLC), which depend on an individual's physical size/stature as well as the anatomical structure of the lungs.^{4,7} Vital capacity represents the maximum amount of gas that can be expired after a maximal inspiration and provides an estimate of the size of the lungs.³ RV is the volume of air that remains in the lungs after a maximal exhalation. Vital capacity and RV are used to determine body composition during underwater weighing.¹⁴ Total lung capacity is the sum of VC plus RV. Lung volumes tend to be larger in tall individuals than in short individuals, and larger in males than females. In a laboratory setting, static lung volumes are measured using a paper tracing from a mechanical spirometer or with an electronic spirometer that provides a digital tracing and computer calculated volumes.

Dynamic tests include forced vital capacity (FVC) and forced expiratory volumes (FEV) and are used to measure rate of airflow to diagnose respiratory disorders such as asthma or emphysema^{2,4,13} (see table 5.1). Forced vital capacity is the volume of air that is exhaled during the entire duration of an FEV test, while FEV represents the volume of air that can be forcefully exhaled in a specified period of time. The FEV1.0 test calculates a forceful expiration across a 1-second period. Figure 5.1 depicts lung volumes and capacities.^{4,13}

Degree of Severity	FEV _{1,0} % Predicted I
Mild	Less than the LLN but ≥ 70
Moderate	60–69
Moderately severe	50–59
Severe	35–49
Very severe	<35

FEV_{1,0} forced expiratory volume in one second; LLN, lower limit of normal

Data derived from *ACSM Guidelines*.²

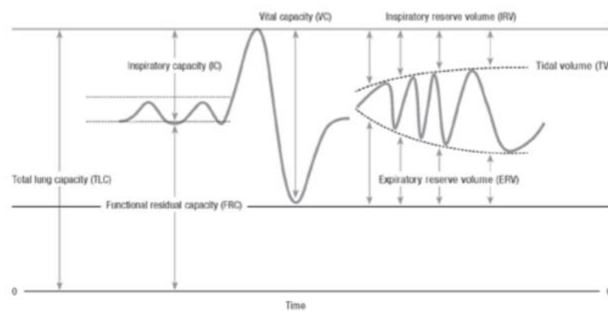


FIGURE 5.1 Lung volumes and capacities.

The measure of ventilation during exercise can provide important information regarding pulmonary function and exercise tolerance.¹³ Dynamic parameters include pulmonary or minute ventilation (VE), breathing rate (BR), tidal volume (TV), and ventilatory equivalent (VE/O₂).¹³ When comparing fit and unfit subjects, a fit subject will produce lower VE, BR, and TV values than the unfit subject at any sub-maximal exercise intensity.¹³ In both populations, however, there is a linear relationship between ventilation and exercise intensity (increase in ventilation with an increase in exercise intensity), while a positive, curvilinear relationship exists between BR, TV, and exercise intensity (BR and TV increase in a linear fashion with exercise intensity before levelling out). A depiction of normal ventilatory kinetics can be seen in figure 5.2.^{4,13}

In normal populations, pulmonary function is not a significant limiting factor to aerobic performance at or below sea level. In clinical populations with pulmonary disorders (i.e., asthma and chronic obstructive pulmonary disease (COPD)), however, the pulmonary system can limit aerobic performance^{12,13} Laboratory procedures that measure lung volumes and capacities are useful in assessing pulmonary function and diagnosing potentially life-threatening conditions.

KNOW THESE TERMS & ABBREVIATIONS^{8,9}

Lung Volumes

- tidal volume (TV) (approximately 500 mL at rest) = reflects the depth of breathing; it is the volume of gas inspired or expired during each respiratory cycle.
- inspiratory reserve volume (IRV) (approximately 1900–3100 mL) = the maximum amount of gas that can be inspired from the end-tidal (the end of a breath) inspiratory level.
- expiratory reserve volume (ERV) (approximately 800–1200 mL) = the maximum volume of gas that can be expired from the end-tidal expiratory level. It is also known as the volume of air present in the resting lungs after a passive exhalation, or resting lung volume (RLV).
- residual volume (RV) (approximately 1000–1200 mL) = the volume of air that remains in the lungs even after a maximal exhalation. After a maximal exhalation, approximately one quarter of total lung capacity (24% for males and 28% for females) will remain as residual volume.

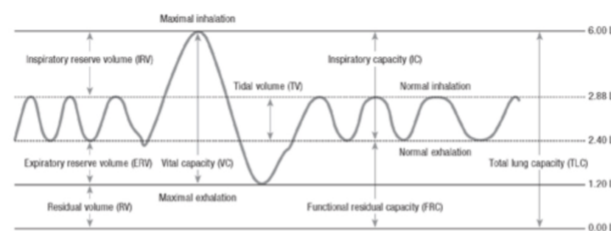


FIGURE 5.2 Normal ventilatory kinetics.

Corrected lung volumes and capacities. TABLE 5.2		
I Measure	Male (mL)	Female (mL)
Tidal volume (TV)	500	500
Inspiratory reserve volume (IRV)	3300	1900
Expiratory reserve volume (ERV)	1000	700
Residual volume (RV)	1200	1100
Vital capacity (VC)	4800	3100
Inspiratory capacity (IC)	3800	2400
Functional residual capacity (FRC)	2200	1800
Total lung capacity (TLC)	6000	4200

Source: Data derived from Martini.⁹

Lung Capacities^{8,9} (table 5.2)

- inspiratory capacity (IC) (approximately 2400–3600 mL) = the maximum amount of gas that can be inspired from the resting expiratory level. It includes the tidal volume and inspiratory reserve volume.
- functional residual capacity (FRC) (approximately 1800–2400 mL) = the amount of gas remaining in the lungs at the resting expiratory level. It includes the expiratory reserve volume and residual volume.
- vital capacity (VC) (approximately 3200–4800 mL) = the maximum amount of gas that can be expired with a forceful effort following a maximal inspiration. It includes the tidal volume, inspiratory reserve volume, and expiratory reserve volume.
- total lung capacity (TLC) (approximately 4200–6000 mL) = the sum of VC and RV.

Ventilation and Pulmonary Measurements^{4,13} (table 5.3)

- BTPS = body temperature pressure (water vapour) saturated; used to refer to the conditions within the lungs.
- BTPS correction factor = used to convert flow and volume measured at ambient conditions within the lungs. Ambient conditions are called ATP (ambient temperature, pressure); the conditions within the lungs are called BTPS.
- minute ventilation (VE) = the amount of air expired in 1 minute.
- breathing rate (BR) = the number of breaths taken each minute.
- ventilatory equivalent (VE/VE/O₂) = the ratio of minute ventilation to oxygen consumption.
- forced vital capacity (FVC) = the total volume of air that is exhaled during the FEV test.
- forced expiratory volume (FEV) = the volume of air that is forcefully expired during a maximal exhalation. It is typically measured in a specific increment of time; for example, 0.5 second, 1 second, and so on.
- forced expiratory volume in 1 second (FEV_{1.0}) = the volume of air that can be forcefully exhaled in 1 second.

TABLE 5.3 Corrected pulmonary function measurement.		
Measure	Male (mL)	Female (mL)
Forced vital capacity (FVC)	4930	3530
Forced expiratory volume at 1 second (FEV _{1.0})	4100	3020
FEV _{1.0} /FEV	83.0	85.5

Source: Data derived from Hankinson.⁶

PROCEDURES^{1,3,4}

Subjects should not smoke, consume a large meal, or consume alcohol within 4 hours of the test. In addition, subjects should wear clothing that will allow full chest and abdominal expansion. Testing should be completed in the seated position unless the subject is unable to fully expand the chest, in which case testing may be conducted while the subject stands. Testers should rehearse the commands and have the subjects practice the breathing manoeuvres prior to each test.

Procedure using SPIROBANK Spirometer.

1. Press 'ON' button.
2. Select 'ESC' using left arrow
3. Select subject using down arrow
4. Select new subject using down arrow again
5. Input date of birth, height, weight and gender by using up and down arrows and OK
6. Select ethnic group by using up and down arrows and OK
7. To begin test, select the graph button using the left arrow.
8. Ensure a clear disposable mouthpiece has been inserted into the spirometer, and the subject is wearing a nose clip.
9. Instruct the subject to place the mouthpiece in their mouth, making a seal around it with their lips, then take a maximal inhalation.
10. The subject should exhale forcefully, for 6s, until an audible beep is heard. It is important to emphasise that the subject must exhale as quickly as possible, particularly in the first second. The subject can now remove the mouthpiece from their mouth.
11. On the laptop, open the app 'Winspiro Express'
12. Enter the name of the client/patient, and connect spirometer via USB cable.
13. Click 'save' to save the results to the laptop.
14. Print the results sheet (ensure laptop is connected to the wifi network 'campusnet' in order to print)- example of results chart is shown below in figure 5.3
15. Record results, then repeat test two more times.
16. Compare results to predicted results (table 5.7) to determine category of lung function.

Figure 5.3 – Example of spirometer result sheet

Pulmonary Function Test Results

Patient Data

Last name	client	Age	44
First name	sample	Gender	Male
Date of birth	04/11/1974	Height, cm	175
Ethnic group	Caucasian	Weight, kg	78

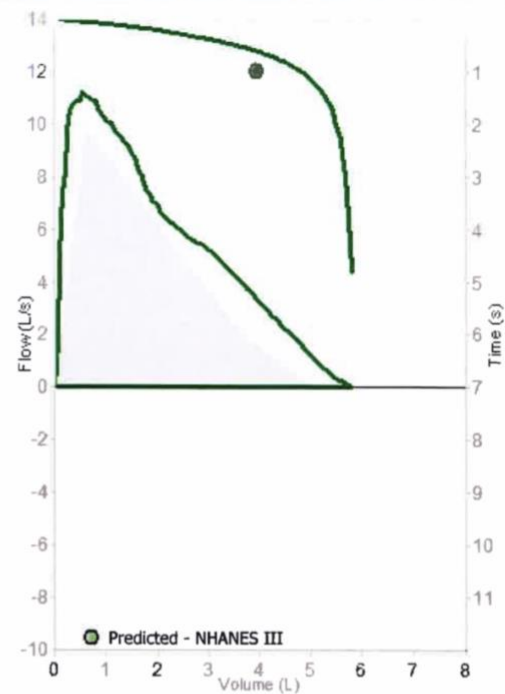
Interpretation

Normal Spirometry

Best values from all loops

Parameters	BTPS	Predicted	Measured	%Predicted
FVC	L	5.02	5.79	115
FEV1	L	3.96	4.90	124
FEV1/FVC	%	79.0	84.6	107
PEF	L/s	9.82	11.23	114

Flow / Volume Loop and Volume / Time Curve



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Parameters	BTPS	Predicted	Measured #1	%Predicted
Forced Vital Capacity				
FEV6	L	4.88	5.79	119
FVC	L	5.02	5.79	115
FEV1	L	3.96	4.90	124
FEV1/FVC	%	79.0	84.6	107
PEF	L/s	9.82	11.23	114
FEF2575	L/s	3.67	5.06	138
ELA	Years	44	44	100
FIVC	L	5.02		

Conclusion / Medical report

TABLE 5.5 Predicted forced vital capacity (FVC_{BTPS}) based on gender, height (cm), and age (y).

Height (cm)	Males Age (y)				Females Age (y)			
	20–24	25–29	30–34	35–39	20–24	25–29	30–34	35–39
155–159	4.29	4.22	4.15	4.06	3.52	3.52	3.50	3.46
160–164	4.58	4.52	4.44	4.35	3.76	3.76	3.74	3.70
165–169	4.89	4.83	4.75	4.66	4.00	4.00	3.98	3.94
170–174	5.21	5.14	5.07	4.98	4.25	4.25	4.23	4.20
175–179	5.53	5.47	5.39	5.30	4.51	4.51	4.49	4.45
180–184	5.87	5.80	5.73	5.64	4.78	4.78	4.76	4.72
185–189	6.21	6.15	6.07	5.98	5.05	5.05	5.03	4.99
190–194	6.56	6.50	6.42	6.33	5.33	5.33	5.31	5.27

Males: $\text{PFVC} = -0.1933 + 0.00064 \times \text{Age} - 0.000269 \times \text{Age}^2 + 0.00018642 \times \text{Ht}^2$

Females: $\text{PFVC} = -0.3560 + 0.0187 \times \text{Age} - 0.00382 \times \text{Age}^2 + 0.00014815 \times \text{Ht}^2$

Source: Data derived from Hankinson et al.⁷

Predicted forced expiratory volume (PFEV_{1.0BTPS}) based on gender, height (cm), and age (y). TABLE 5.6

Height (cm)	Males Age (y)				Females Age (y)			
	20–24	25–29	30–34	35–39	20–24	25–29	30–34	35–39
155–159	3.66	3.55	3.44	3.31	3.09	3.03	2.95	2.87
160–164	3.88	3.78	3.66	3.54	3.28	3.21	3.14	3.05
165–169	4.12	4.01	3.89	3.77	3.47	3.40	3.33	3.24
170–174	4.35	4.25	4.13	4.01	3.66	3.60	3.52	3.44
175–179	4.60	4.49	4.38	4.25	3.86	3.80	3.72	3.64
180–184	4.85	4.75	4.63	4.51	4.08	4.00	3.93	3.84
185–189	5.11	5.01	4.89	4.77	4.28	4.21	4.14	4.05
190–194	5.38	5.27	5.16	5.03	4.50	4.43	4.36	4.27

Males: $\text{PFEV}_{1.0} = 0.5536 - 0.01303 \times \text{Age} - 0.000172 \times \text{Age}^2 + 0.00014098 \times \text{Ht}^2$

Females: $\text{PFEV}_{1.0} = 0.4333 - 0.00361 \times \text{Age} - 0.000194 \times \text{Age}^2 + 0.00011496 \times \text{Ht}^2$

Source: Data derived from Hankinson et al.⁷

Category of lung function including degrees of lung restriction or obstruction. TABLE 5.7

Classification	% Predicted
High lung function	≥ 120%
Good lung function	100–119%
Normal lung function	80–99%
Mild restriction (FVC) or obstruction (FEV)	65–79%
Moderate restriction (FVC) or obstruction (FEV)	50–64%
Severe restriction (FVC) or obstruction (FEV)	35–49%
Very severe restriction (FVC) or obstruction (FEV)	< 35%

FVC = forced vital capacity

FEV = forced expiratory volume

Source: Data derived from Morris.¹⁰

REFERENCES

1. American College of Chest Physicians. Clinical spirometry: recommendations of the section on pulmonary function testing committee on pulmonary physiology. *Dis. Chest* 4: 214; 1963.
2. American College of Sports Medicine. ACSM's Guidelines for Exercise Testing and Prescription, 9th edition. Baltimore: Wolters Kluwer/Lippincott Williams & Wilkins, 2014.
3. American Thoracic Society. Lung function testing: selection of reference values and interpretative strategies. *Am. Rev. Respir. Dis.* 144: 1202–1218, 1991.
4. Beam, W., and Adams, G. Exercise Physiology Laboratory Manual, 7th edition. New York: McGraw-Hill, 2014.
5. DuBois, A. B., Botelho, S. Y., Bedell, G. N., Marshall, R., and Comroe Jr., J. H. A rapid plethysmographic method for measuring thoracic gas volume: a comparison with a nitrogen washout method for measuring functional residual capacity in normal subjects. *J. Clin. Invest.* 35 (3): 322, 1956.
6. Hankinson, J. L., Crapo, R. O., and Jensen R. L. Spirometric reference values for the 6-s FVC maneuver. *Chest* 124: 1805–1811, 2003.
7. Hankinson, J. L., Odencrantz, J. R., and Fedan, K. B. Spirometric reference values from a sample of the general U.S. population. *Am. J. Respir. Crit. Care Med.* 159: 179–187, 1999.
8. Housh, T. J., Housh, D. J., and DeVries, H. A. Applied Exercise and Sport Physiology, 4th edition. Scottsdale, AZ: Holcomb Hathaway, 2016.
9. Martini, F. H., Ober, W. C., Garrison, C. W., Welch, K., and Hutchings, R. T. Respiratory physiology. In *Fundamentals of Anatomy and Physiology*, 3rd edition. Englewood Cliffs, NJ: Prentice-Hall, 1995, pp. 846–858.
10. Morris, J. F. Spirometry in the evaluation of pulmonary function. *West. J. Med.* 125: 110–118, 1976.
11. Universities Occupational Safety and Health Educational Resource Center. NIOSH Spirometry Training Guide. Morgantown, WV, December 2003.
12. Wasserman, K., Hansen, J. E., Sue, D. Y., Stringer, W. W., Sietsema, K. E., Sun, X., and Whipp, B. J. *Principles of Exercise Testing and Interpretation: Including Pathophysiology and Clinical Applications*. Philadelphia: Lippincott Williams & Wilkins, 2011.
13. Wilmore, J. H. A simplified method for determining residual volume. *J. Appl. Physiol.* 27: 96–100, 1968.
14. Wilmore, J. H., Vodak, P. A., Parr, R. B., Girandola, R. N., and Billing, J. E. Further simplification of a method for determination of residual volume. *Med. Sci. Sports Exerc.* 12 (3): 216–218, 1979.