42 Aero Camino, Goleta, CA 93117

www.biopac.com

Biopac Student Lab® Lesson 13

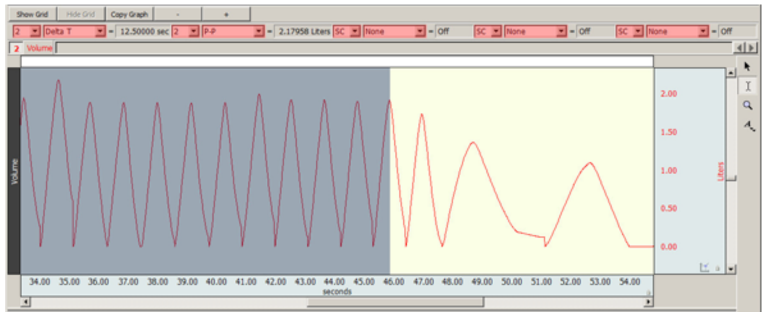
PULMONARY FUNCTION II

Introduction

Rev. 01152013

Richard Pflanzer, Ph.D.
Associate Professor Emeritus
Indiana University School of Medicine
Purdue University School of Science

William McMullen
Vice President, BIOPAC Systems, Inc.



I. Introduction

The **respiratory** or **pulmonary** system performs the important functions of supplying oxygen (O_2) during inhalation, removing carbon dioxide (CO_2) during exhalation, and adjusting the acid-base balance (pH) of the body by removing acid-forming CO_2. Because oxygen is necessary for cellular metabolism, the amount of air that the pulmonary system provides is important in setting the upper limits on work capacities or metabolism. Therefore, the measurement of lung volumes and the rate of air movement (airflow) are important tools in assessing the health and capacities of a person.

In this lesson, you will measure:

- **Forced Vital Capacity** (FVC,) which is the maximal amount of air that a person can forcibly exhale after a maximal inhalation.
- **Forced Expiratory Volume** (FEV,) which is the percentage of FVC that a person forcibly expels in intervals of 1, 2, and 3 seconds. ($FEV_{1.0}$, $FEV_{2.0}$, $FEV_{3.0}$)
- **Maximal Voluntary Ventilation** (MVV,) which is a pulmonary function test that combines volume and flow rates to assess overall pulmonary ventilation.

These measurements indicate the upper limit of work that the person can do based on the capabilities of his or her respiratory system. When a person takes in maximal inhalation and then follows this with maximal exhalation the volume of expired air is that person's **Single Stage Vital Capacity** (SSVC). The time required to achieve maximal exhalation is not a factor in determining SSVC.

Because the lungs reside in the thoracic cavity, vital capacity is ultimately restricted by the size of a person's thoracic cavity. Therefore, size-related variables (e.g., age, gender, weight) affect the capacities of the respiratory system (Table 13.1).

Using the equation in Table 13.1, you can estimate the vital capacity of a 19 year old female who is 167 centimeters tall (about 5'6") as 3.815 liters:

$$0.041 \times (167) - 0.018 \times (19) - 2.69 = 3.815 \text{ liters}$$

For adults, the average pulmonary capacities decrease with age. Women tend to have smaller volumes than men of the same age and weight. As weight increases, volumes increase, with the exception that overweight people tend to have decreased volumes.

Table 13.1

Equations for Predicted Vital Capacity (Kory, Hamilton, Callahan: 1960)	
Male	V.C. = 0.052H - 0.022A – 3.60
Female	V.C. = 0.041H - 0.018A – 2.69

V.C. Vital Capacity (L) **H** Height (cm) **A** Age in years

Even within one person, respiratory supply and demand differs with activity levels and health. Accordingly, the rate and depth of **ventilation** (the volume of gas you breathe in and out per minute) are not static but rather must constantly adjust to the changing needs of the body. As you increase your activity levels from rest, the volume and rate of air flowing in and out of your lungs also changes. The changes in volume and how fast those changes in volume (airflow) are effected can be used to assess the health of a person's respiratory system.

Pulmonary volumes, pulmonary capacities, and pulmonary airflow rates are often measured in diagnosing and assessing the health of the respiratory system (Fig. 13.1).

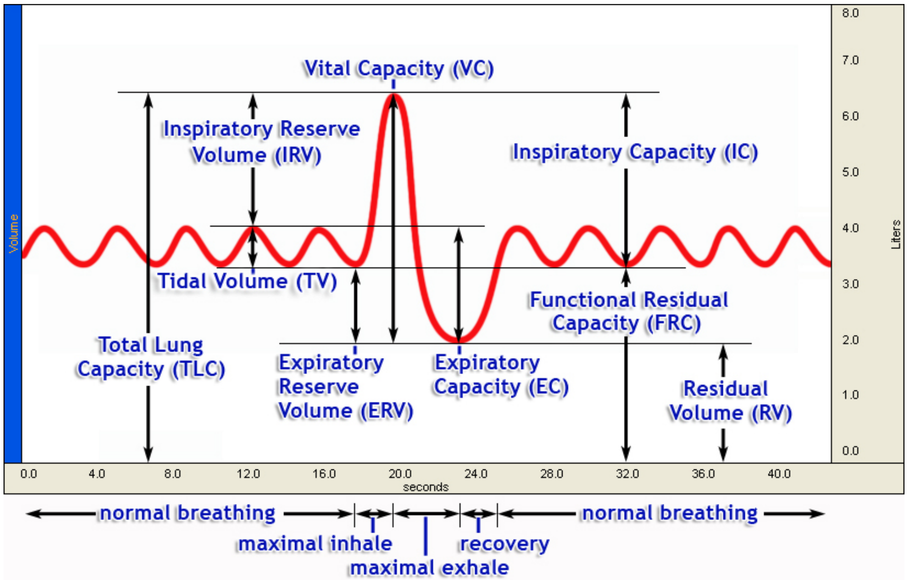


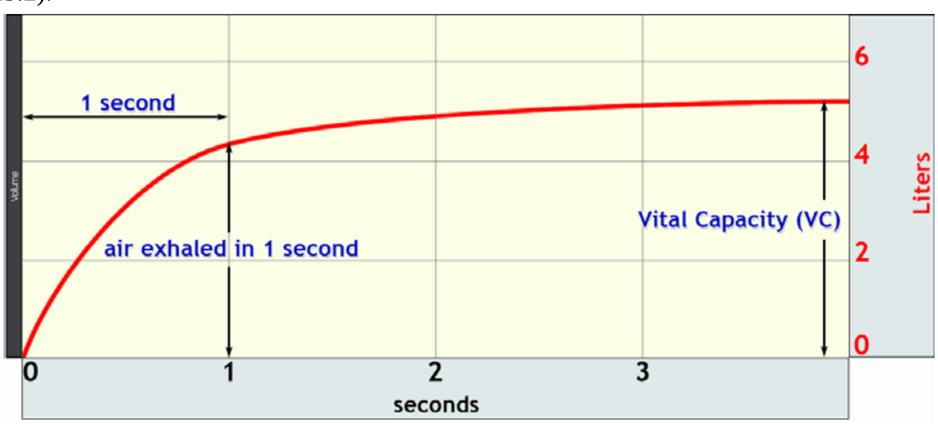
Fig. 13.1 Examples of commonly measured pulmonary volumes and capacities

In this lesson, you will perform two tests to measure pulmonary flow rates:

1. Forced Expiratory Volume (FEV)
2. Maximal Voluntary Ventilation (MVV)

Test #1: Forced Expiratory Volume (FEV)

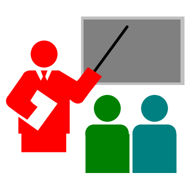
Forced Expiratory Volume (also referred to as forced vital capacity or timed vital capacity) is a test in which a limit is placed on the length of time a Subject has to expel vital capacity air. $FEV_{1.0}$, $FEV_{2.0}$, $FEV_{3.0}$ are defined as the percentage of vital capacity that can be forcibly expelled after a maximal inhalation in the period of one second, two seconds, and three seconds, respectively (Fig. 13.2).



$$FEV_{1.0}(\%) = \frac{\text{volume of air expired in 1 second}}{\text{Vital Capacity (VC)}} \times 100$$

Fig. 13.2 Section of a record of Forced Expiratory Volume in one second ($FEV_{1.0}$)

The normal adult is able, with maximal effort, to expire about 66-83% of his/her vital capacity in one second ($FEV_{1.0}$,) 75-94% of vital capacity in the second second ($FEV_{2.0}$,) and 78-97% of vital capacity by the end of the third second ($FEV_{3.0}$).



A person with asthma may have a normal or near-normal vital capacity as measured in a Single Stage Vital Capacity test, which allows as long as necessary to maximally inhale and exhale. However, when an asthmatic exhales vital capacity with maximal effort, FEV measurements are all reduced because heavy mucus secretion and smooth muscle action reduces airway diameter and it takes longer to completely exhale vital capacity against increased airway resistance.

Test #2 Maximal Voluntary Ventilation (MVV)

The Maximal Voluntary Ventilation (also known as *maximal breathing capacity*) measures peak performance of the lungs and respiratory muscles. MVV is calculated as the volume of air moved through the pulmonary system in one minute while breathing as quickly and deeply as possible (hyperventilation). In performing this test, Subject inspires and expires as deeply and as rapidly as possible (> 1 breath/sec) while the tidal volume and the respiratory rate are measured. Because the maximal breathing rate is difficult to maintain, Subject hyperventilates for a maximum of 15 seconds. Then, to calculate MVV, the average volume per respiratory cycle (liters) is multiplied by the number of cycles per minute (liters/min).

MVV can also be extrapolated from the total volume of air moved in a 12-sec period (total volume in 12-sec X 5 = MVV).

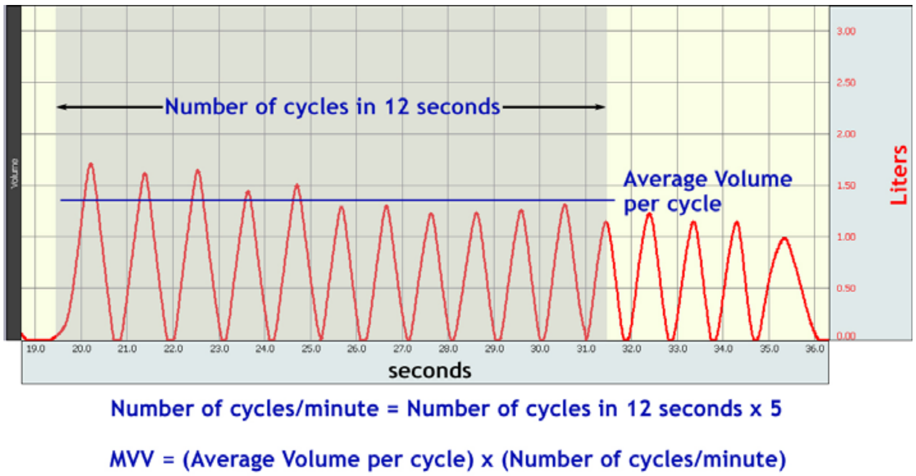
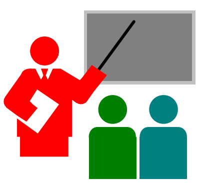


Fig. 13.3 MVV example

Normal values vary with sex, age and body size. MVV is a measure of how much your pulmonary system limits your capacity to work or exercise.



You can rarely exceed your MVV, even for brief periods of time. Therefore, MVV ultimately limits how much oxygen is available for exercising muscles. In general, a maximum of 50% of your MVV can be used for exercise beyond 10 minutes. Most people have trouble breathing when only using the available 30-40% MVV. MVV tends to be reduced in both restrictive and obstructive pulmonary diseases.