Respiratory System and Spirometry

Objective:

To explain in words or diagrams the mechanical events responsible for movement of air into and out of the lungs and to relate these mechanical events to respiratory volumes and capacities, at the level of 85% proficiency for each student.

In order to achieve this objective, you will need to be able to:

1. Explain the role of muscles and volume changes in the mechanical process of breathing
2. Define VC, TV, IRV, and ERV and provide volume figures if applicable.
3. Measure movement of air out of the lungs by way of a non-recording spirometer.

Materials:

Lab Materials:

Model lung (bell jar demonstrator)
Tape measure
Disposable mouthpieces

Group Materials

Spirometer

Mechanics of Respiration

Methods and Results:

The thorax and lungs are modeled using a simple apparatus with a bottle “thorax,” a rubber membrane "diaphragm," and "balloon lungs." The model demonstrates the processes involved in gas flows into and out of the lungs.

Move the rubber membrane "diaphragm." Notice the changes in balloon (lung) size as the volume of the thoracic cavity is alternately increased and decreased.

After observing the operation of the thorax and lung model, conduct the following tests on your lab partner. Use a tape measure to determine his or her chest circumference by placing the tape around the chest as high up under the armpits as possible.

Record the measurements in inches in the appropriate space for each of the conditions below.

Chest circumference Quiet breathing:

Inspiration _____ expiration _____

Chest circumference Forced breathing:

Inspiration _____ expiration _____

Do the results coincide with what you expected based on what you have learned thus far?

Respiratory Volumes and Capacities – Spirometry

Methods:

Respiratory volumes will be measured with an apparatus called a **spirometer.** In non-recording spirometers, an indicator moves as air is *exhaled,* and only exhaled air volumes can be measured directly. By contrast, recording spirometers allow both inspired and expired gas volumes to be measured.

We will be using non-recording spirometers, and their operation will be explained in the lab.

In this lab we will measure respiratory rate (RR), tidal volume, (TV), exhalatory reserve volume (ERV), and vital capacity (VC). In addition, we will calculate inhalatory reserve volume (IRV) and minute respiratory volume (MRV).

1. Repeat measurement three times. Record the data in the table - Respiratory Rates and Volumes, and then find the average value for each respiratory measurement. After you have completed the trials and computed the averages, enter the average values on the table prepared on the chalkboard for tabulation of the class.

2. **Respiratory Rate**. The numbers of breaths each minute. Without using the spirometer, count and record the subject's resting respiratory rate. Measure three times and record.

3. **Tidal volume (TV)**. The volume of air inhaled and exhaled with each breath under typical conditions (approximately 500 mL). Practice inhaling and exhaling normally two or three times. To measure TV, inhale a normal breath, place the mouthpiece in your mouth and then exhale a normally into the spirometer. (Do not force the exhalation!). Repeat three times and record the results.

4. **Exhalatory reserve volume (ERV)**. The volume of air that can be forcibly exhaled after a normal tidal volume expiration (ranges between 1000 and 1200 mL). Inhale and exhale normally two or three times. To measure ERV, exhale normally, place the mouthpiece in your mouth and then exhale forcibly into the spirometer. Repeat three times and record the results.

   The ERV is dramatically reduced in conditions in which the elasticity of the lungs is decreased by a chronic obstructive pulmonary disease (COPD) such as **emphysema**. Since energy must be used to *deflate* the lungs in such conditions, expiration is physically exhausting to individuals suffering from COPD.

5. **Vital capacity (VC)**. The total exchangeable air of the lungs (the sum of TV + IRV + ERV) is normally 3800 mL to 4800 mL. Inhale and exhale normally two or three times. To measure VC, inhale as much air as possible, place the mouthpiece in your mouth and then exhale as forcibly as possible into the spirometer. Repeat three times and record the results.

6. **Inhalatory reserve volume (IRV)**. The volume of air that can be forcibly inhaled following a normal tidal volume inspiration (ranges between 2100 mL and 3100 mL). IRV can be computed using the average values obtained for TV, ERV, and VC and plugging them into the equation:

$$IRV = VC - (TV + ERV)$$

7. **Minute respiratory volume (MRV)**. The volume of air that is exhaled each minute. MRV can be computed using the average values obtained for RR and TV and plugging them into the equation:

$$MRV = RR \times TV$$

8. When recording is finished for each subject, and before continuing with the next member of your group:

    a. Dispose of used cardboard mouthpieces.
    b. Put a fresh mouthpiece into the valve assembly and continue recording the next member of your group using the procedures outlined above.

Results:

Respiratory Rates and Volumes

	trial 1	trial 2	trial 3	Average
Respiratory Rate (RR)				
Tidal Volume (TV)				
Exhalatory Reserve Volume (ERV)				
Vital Capacity (VC)				
Inhalatory Reserve Volume (IRV)				
Minute Respiratory Volume (MRV)				

1. The typical IRV is substantial, ranging from 2100 to 3100 mL. How does your computed value compare with a typical IRV?

   _____

2. Figure out how closely your measured average vital capacity volume compares with the *predicted values of vital capacity (VC)* for someone your age, sex, and height. The equations for the predicted values were derived by D. G. Ward using a multivariate regression analysis of a large pool of human data. For these equations, age is expressed in years, and height is expressed in centimeters (cm). The latter is easily done by multiplying your height in inches by 2.54.

   Height in inches: _____ in. Height in centimeters: _____ cm

   Predicted VC male = Age x (-19.6) + Height x (22.9) + 788

   Predicted VC female = Age x (-16.5) + Height x (17.7) + 788

   Predicted VC: _____ mL

3. Use this equation to compute your measured VC as a percentage of the predicted VC:

$$\text{Percentage of predicted VC} = \frac{\text{averaged measured VC}}{\text{predicted VC}} \times 100$$

   = _____ %

4. A respiratory volume that cannot be experimentally demonstrated here is the residual volume (RV), which is the amount of air remaining in the lungs after a maximal Exhalatory effort. The presence of residual air (usually about 1200 mL) that cannot be voluntarily pushed from the lungs is important because it prevents the lungs from collapsing and allows gas exchange to go on continuously — even between breaths.

   Although the residual volume (RV) cannot be measured directly here, it can be approximated from your vital capacity (VC) by using one of the following factors.

   For ages 16 — 34; factor = 0.250

   For ages 35 — 49; factor = 0.305

   For ages 50 — 69; factor = 0.445

   Compute your predicted RV from your vital capacity (VC) using the following equation:

   RV = VC x factor = _____

Discussion

1. Under what conditions are changes in chest circumference measurable? Explain why.
2. Explain how to use TV and RR to calculate MRV.
3. Explain how VC, ERV, and IRV can be used to help diagnose respiratory disorders.
4. Speculate why RV increases with increasing age.