Respiratory Mechanics: Experimental Procedures

Throughout these experiments, record in your notebook the purpose of the experiments, the methods you used, and the results. Where possible, make predictions before conducting the experiments. Include the measurement uncertainties and state their main sources. Feel free to include commentary or ideas that you develop along the way. After the lab period, write up your statistical analysis, and discussion/conclusions (you may combine these). Include the answers to any specific questions that are asked in the lab procedure. It is recommended that you answer these questions after you have completed all of the data collection. You do not have to do parts 1, 2 and 3 in order.

Part 1: Inspiratory and expiratory pressures

Make the following predictions and measurements, entering the values in your notebook using the format tabulated below.

1. Predict the pressure that you can achieve by exhaling through a tube into a manometer or pressure gauge. Express the pressure as Pascals, psi, meters of water, and mm of mercury.
2. Predict the negative pressure (vacuum) that you can achieve by inhaling against a closed volume. Express the pressure as Pascals, psi, m of water, and mm of mercury.
3. Use an electromechanical pressure gauge to determine your maximum expiratory pressure. If you use the GPS-BTA gas pressure sensor with the LabPro hardware and Logger Pro, **do not exceed 200 kPa of applied pressure**. Verify the pressure gauge operation using a syringe, expanding and compressing the air by a factor of 2. Note any hysteresis in the gauge.[2] Use alcohol wipes to disinfect any connections that will come in contact with your mouth.
4. Use the air pressure gauge to determine your maximum inspiratory pressure.
5. (Optional) Connect a gas pressure sensor to a spirometer to obtain the correlation between volume and pressure as a function of time.
6. (Optional) Conduct an experiment to determine the extent to which your maximum inspiratory pressure is determined by the volume of air remaining in your lungs. One suggestion is to connect the gas pressure sensor to the respirometer and see how your lung pressure varies with inspired/expired volume. An alternative is to insert a 3-way valve in the gas-pressure-sensor system, such that air can be expelled in steps, reducing the lung volume by a small amount between pressure measurements.

Related questions

Q1. Compare the pressures observed above to typical systolic and diastolic blood pressures.

Q2. Estimate the frontal area of your lungs (the size they would appear in a radiographic image, i.e. an x-ray). Use this value and the maximum inspiratory pressure to estimate the differential force acting on your thorax.

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[2] **Hysteresis** is the tendency of a system or measurement to return to some non-zero value after a load has been removed from it. The measurement can be returned to zero by applying the opposite load.

Part 2: Measurement of Lung Volumes and Lung Capacities

Procedure: *Measurement of lung volumes and capacities.*

Each subject should be assigned a unique identifier that consists of the lab section, randomly assigned group number, and letter for each member. For example, a particular subject in lab section B might be B2a (section B, group 2, member a).

In order to give everyone some time with a spirometer, each team should collect data for no more than 40 minutes. Within this time, collect data for as many team members as you can. Once the team has collected its measurements, post the data to the lab section discussion board in an Excel, csv or text file. Please use the standard abbreviations to head the columns in your spreadsheet. Optional: provide your weight, height, sex, and relative fitness level for each subject; you may choose to omit any or all of this information.

Each **Ohio 822 spirometer** has a piston with an internal diameter of approximately 29.6 cm. Calculate the displacement ratio in L/mm for the pen traces produced by this spirometer. For parts (a) through (d), set the chart recorder speed to the slower setting. In order to avoid wasting paper, the operator should start the machine just before the subject starts the described breath. Before each trial, determine the logical starting position for the pen, considering the range of volume that you expect the cylinder to contain during the trial. When you are done with the spirometer, manually expel the air from the cylinder.

The **Koko spirometer** is a USB device that performs a variety of lung volume calculations for you. You may use the automatically calculated results, but it is often simpler and more educational to obtain values by measuring the plots and then do your own calculations.

- **a)** Vital Capacity (VC). The subject inhales to maximum capacity, then blows air into the spirometer to his or her maximum capacity, at a comfortable flow rate. Record the volume. Repeat the procedure two more times allowing a brief rest between successive measurements.
- **b)** Tidal Volume (TV). Generate a V vs. t trace as the subject breathes normally for 4-5 breaths. Measure and record the mean peak-to-trough volume range.
- **c)** Inspiratory Reserve Volume (IRV). At the end of a normal inspiration, have the subject inhale maximally. Determine the additional volume of air inspired.
- **d)** Expiratory Reserve Volume (ERV). Allow the subject to breathe normally for 2-3 breaths and at the end of a normal expiration continue to exhale until maximum capacity is attained.

For part (e) set the chart recorder speed to the faster setting. The operator should start the machine just before the subject starts the described breath.

- **e)** Forced Expiratory Volume (FEV_1). As in part (b), take as deep a breath as possible before placing the mouthpiece in the mouth. Expel air into the mouthpiece as rapidly and completely as possible. Divide the volume expelled in one second by the total volume expelled to determine the percentage expelled in the first second.

Record your group's measurements in a spreadsheet in the following order.

Subject	VC	TV	IRV	ERV	FEV_1	RR	Sex	Height	weight	age

Upload your group's spreadsheet of measurements to the discussion board. Do it as soon as you have compiled the data. If you do not include the Sex, Height, Weight, and Age data, then include your calculated residual volume.

For the Lab Report

a) Provide the purpose, methods, and raw results.

b) Compare your results with expected values as tabulated in the introduction. Explain why you might observe differences from the expected values.

c) Calculate the volumes and capacities listed in the second table below. Use the formulas provided above to estimate the residual volume. Tabulate them in the order shown.

Subject	RV	TLC	FRC	IC	RMV	VC	100*FEV_1/ VC

d) For each of the values you measured and calculated, provide the mean and standard deviation over the entire lab section. Compare the mean TLC for those subjects who provided their weight and those who did not.

e) Use Excel's or MATLAB's linear regression tool to determine the correlation between TLC and height, and TLC and weight.

f) In what types of disorders would you expect an abnormally low fraction of the vital capacity to be exhaled in one second?

Calculations & Questions

a) Determine the volumetric flow rate of air during the first second. Assuming that the diameter of the trachea is 2 cm, calculate the Reynolds number of the air flow in the trachea. Re = density*diameter*velocity/viscosity.

b) Air is compressible, but in fluid dynamics the term "compressible flow" is used when the flow speed is greater than about 20% of the speed of sound. This ratio of velocity to speed of sound is called the Mach number. Find the Mach number in the trachea at the time of maximal flow.

c) The air in the lungs provides a large portion of the buoyant force on our bodies when submerged. Calculate the difference in buoyancy provided by the air in your lungs after a forced inspiration while treading water (the lungs are fully submerged to an average depth of 0.2 m) to the force when submerged to a depth of 3 m (e.g. when kneeling on the bottom of a 12-ft-deep swimming pool).

Part 3: Physiologic Control of Breathing and Heart Rate

This station uses a spirometer, stethoscope, and blood pressure monitor.

Procedure

For each of the following steps, it is sufficient for a team to take measurements on one person in the team and then share the data with the rest of the team.

a) With the subject at rest, establish baseline values for breathing rate, pulse rate and blood pressure. If a spirometer is available, measure tidal volume as well.

b) Have the subject run to the 5th floor and back, then record BR, BP and HR before (and volumetric values if available). Repeat approximately every 2 minutes until these variables return to within 10% of baseline. Your rate of data collection will probably be limited by the amount of time it takes to measure blood pressure. If time permits, repeat the exercise.

c) Optional, if the instrumentation is available: Sterilize the end of a long tube with alcohol. Have the subject breathe through this tube while monitoring the physiological conditions as well as O_2 and CO_2 content in the breath until conditions can no longer be safely tolerated. Repeat with a tube of a different volume.

For Lab Writeup

Include the standard purpose, methods, results, and discussion, focusing on the following information. Letters in this Writeup section correspond to letters in the procedure.

a) What were the resting and exercising values of the breathing rate, pulse rate, blood pressure, and (if available) breathing volumes?

b) Of the three or four values measured, which appears to be the most affected by exercise? Comment on your observations and suggest causes.

c) Is there an observable difference between O_2 and CO_2 content in small vs. large diameter tubes? Explain why you think this would be.