Experiment HE-4: Respiratory Exchange Ratio (RER)

Background

The two sources of energy available for human metabolism are carbohydrates (CHO) and fats. These molecules are broken down, or catabolized, into carbon dioxide, water, and energy. However, the oxidation of fats requires more oxygen than the oxidation of carbohydrates.

The oxidation of a molecule of carbohydrate is expressed by the following equation:

$$6\ O_2 + C_6H_{12}O_6 = 6\ CO_2 + 6\ H_2O + 38\ ATP$$

As shown in this equation, 6 molecules of carbon dioxide are produced for every 6 molecules of oxygen consumed during the oxidation of carbohydrates, a ratio of 1.0.

The oxidation of a molecule of fatty acid is expressed by this equation:

$$23\ O_2 + C_{16}H_{32}O_2 = 16\ CO_2 + 16\ H_2O + 129\ ATP$$

As shown in this equation, 16 molecules of CO_2 are produced for every 23 molecules of O_2 consumed during the oxidation of fatty acids, a ratio of 0.7.

The energy requirements of the body are met with a mixture of energy derived from carbohydrates and fats. The activity being performed determines the proportion of carbohydrates and fats being utilized. At rest, a body derives about 40% of its energy from carbohydrates and 60% from fats. As the intensity of activity increases, the demand for energy increases, and a greater proportion of this demand is met by the oxidation of carbohydrates. When maximal oxygen uptake is occurring at the most intense exercise level, 100% of the energy is being supplied by carbohydrates because the catabolism of fat is too slow to supply the amount of energy required.

As the ratio of energy supplied by fats and carbohydrates shifts during changes in activity, the ratio of carbon dioxide produced to oxygen consumed also shifts. The ratio of carbon dioxide produced to oxygen consumed during cellular metabolism can be measured by determining the changes in the concentrations of oxygen and carbon dioxide in the air that passes into and out of the lungs. These measurements are possible because the amounts of oxygen and carbon dioxide exchanged between the alveoli and the capillaries in the lungs are directly dependent on the amounts of carbon dioxide produced and oxygen consumed during cellular respiration.

The amounts of oxygen consumed and carbon dioxide produced are measured using an oxygen/carbon dioxide gas analyzer connected to a spirometer. The gas analyzer measures the concentration of oxygen and carbon dioxide in inspired and expired air, and the spirometer determines the volumes of inspired and expired air. When the concentrations and volumes are brought together in a series of equations, the volume of oxygen consumed per minute, known as VO_2, and the volume of carbon dioxide produced per minute, known as VCO_2 are determined. The ratio of VCO_2/VO_2 is the Respiratory Exchange Ratio (RER), which can be used to determine the proportion of carbohydrates and fats utilized, and the energy expended per liter of oxygen consumed, during an activity (Table HE-4-B1).

The fat and carbohydrate percentages utilized during an activity are determined using the following equations:

$$((1.00\text{-RER})/(1.00\text{-}0.70)) \times 100 = \%\text{Fat utilized}$$

$$100\% - \%\text{Fat utilized} = \%\text{CHO utilized}$$

The energy expended during an activity is calculated from the RER and the volume of oxygen consumed. For example, if the RER is 0.90, the energy expended is 4.92kcal/liter O_2. If 2.5 liters of oxygen are consumed per minute for 20 minutes, a total of 246 kcal are expended during the activity:

$$(2.5LO_2/\text{minute})(20\text{min})(4.92\text{kcal/liter } O_2) = 246\text{kcal}$$

At less intense activity levels, the rates of energy expenditure and RER values are lower. To expend the same amount of energy at a less intense level of activity, the duration of activity must be longer. For example, if the RER is 0.80, the energy expended is 4.80kcal/liter O_2. If 1.7 liters of oxygen are consumed per minute, 8.16kcal are expended per minute:

$$(1.7LO_2/\text{minute})(4.80\text{kcal/liter } O_2) = 8.16\text{kcal/min}$$

To expend 246 kcal at a rate 8.16kcal/min would require 30 minutes, 9 seconds:

$$246 \text{ kcal}/(8.16 \text{ kcal/min}) = 30.15 \text{ minutes.}$$

Table HE-4-B1: Respiratory Exchange Ratio (RER) as a Function of the Proportions of Energy Sources.

RER	Energy kcal/liter O_2	% Energy from CHO	% Energy from Fats
0.70	4.69	0	100
0.75	4.74	15.6	84.4
0.80	4.80	33.4	66.6
0.85	4.86	50.7	49.3
0.90	4.92	67.5	32.5
0.95	4.99	84.0	16.0
1.00	5.05	100	0

In this experiment, students will measure the VO_2, VCO_2, RER, and proportion of fat and carbohydrates utilized while the subject is resting, hyperventilating, recovering from hyperventilation, and recovering from light or moderate exercise. These measurements will be performed quickly and easily using an iWire-GA CO_2/O_2 gas analyzer that is connected to a spirometry system.

Experiment HE-4: Respiratory Exchange Ratio (RER)

Equipment Required

PC or Mac Computer

IXTA data acquisition unit, power supply, and USB cable

Flow head tubing and A-FH-1000 flow head

A-GAK-201 Reusable mask and non-rebreathing valve

6ft Smooth-bore tubing (35mm I.D.)

5 Liter Mixing Chamber

Nafion gas sample tubing

iWire-GA CO_2/O_2 Gas Analyzer with filter

A-CAL-150 Calibration kit

3 Liter Calibration syringe

Setup the IXTA and iWire-GA

1. Connect the iWire-GA to the iWire1 port on the front of the IXTA, and plug it into the wall using the power supply.
2. Plug the IXTA into the wall and, using the USB cable, to the computer.

NOTE: The iWire-GA must be plugged into the IXTA prior to turning both machines on.

3. Turn on the IXTA and the iWire-GA.
4. Open LabScribe.
5. Click Settings → Human Exercise-iWireGA → VO2-RER.
6. Once the settings file has been loaded, click the **Experiment** button on the toolbar to open any of the following documents:
   - Appendix
   - Background
   - Labs
   - Setup (opens automatically)

Setup the Metabolic Cart

1. Locate the A-FH-1000 flow head and tubing in the iWorx kit (Figure HE-4-S1).

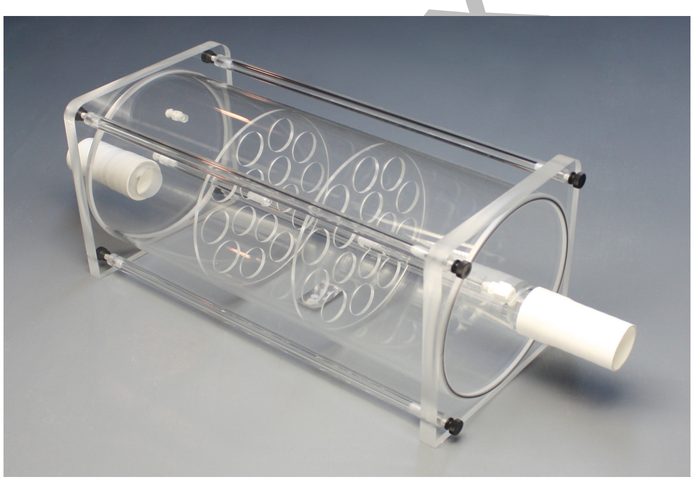
Figure HE-4-S1: The A-FH-1000 flow head, and airflow tubing.

2. Carefully attach the two airflow tubes onto the two sampling outlets of the A-FH-1000 flow head and the other ends of the two airflow tubes onto Channel A1 on the front of the IXTA (Figure HE-4-S4).

Note: *Make sure to connect the airflow tubing so that the ribbed tube is attached to the red outlet port of the flow head and also to the red inlet port of the spirometer. The smooth side of the tubing attaches to the white ports.*

3. Locate the mixing chamber in the iWorx kit (Figure HE-4-S2).
4. Connect the inlet of the A-FH-1000 flow head to the outlet of the mixing chamber (Figure HE-4-S3).

Note: *Be sure to connect the flow head to the mixing chamber so that the red outlet port is facing towards the mixing chamber.*



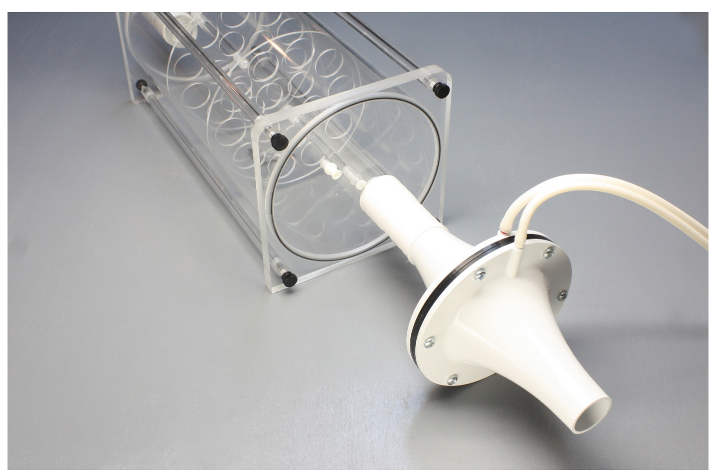


Figure HE-4-S2 and HE-4-S3: The mixing chamber showing the 1000L/min flow head connected to the outlet.

5. Locate the non-rebreathing valve, mask, and smooth interior tubing in the iWorx kit (Figure HE-4-S5).
6. Attach one end of the smooth interior tubing to the inlet of the mixing chamber (Figure HE-4-S6), and the other end to the outlet of the non-rebreathing valve. There are arrows on the valve that indicate the direction of air flow.
7. Attach the mask to the side port of the non-rebreathing valve.

Figure HE-4-S4: The iWire-GA gas analyzer connected to an IXTA. All tubings are connect properly in this image.

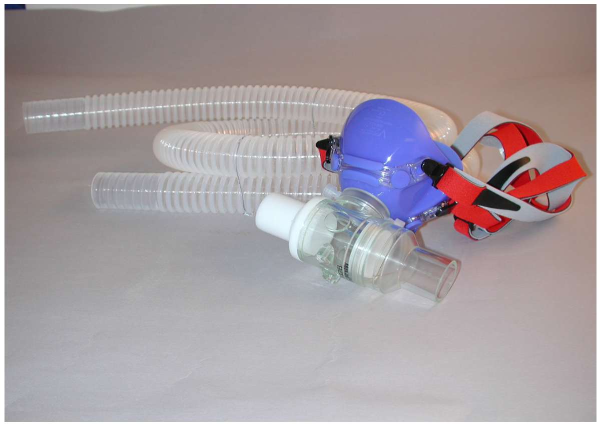


Figure HE-4-S5: Mask, non-rebreathing valve, and smooth interior tubing.

8. On the iWire-GA, place one filter on the “Room Air” port, place a second filter on the “Sample In” port. Attach the braided end of the Nafion sampling tube to the filter on the “Sample In” port.
9. Place the other end of the Nafion sampling tube on the gas sampling port near the outlet of the mixing chamber (Figure HE-4-S6).

Figure HE-4-S6: The assembled devices used during metabolic studies. The assembly includes: the mixing chamber, smooth interior tubing, Nafion sampling tubing, flow head, spirometer, non-rebreathing valve, and mask.

10. Plug the outlet tubing from the iWire-GA to the port on the mixing chamber, opposite the flow head.

The non-rebreathing valve can be used with the attached mask or with an optional mouthpiece.

If the subject is using a mask (preferred method):

- Attach the head gear to the mask.
- Attach the non-rebreathing valve to the mask. Depending on the model of the mask, an adapter may be required.
- Instruct the subject to try on the assembly. Adjust the straps so that the mask fits the subject comfortably. Make sure there are no leaks around the mask.

If the subject is using a mouthpiece:

- Attach the headgear to the brackets on the non-rebreathing valve. The pair of straps with the narrowest spacing go over the top of the subject's head.
- Connect the mouthpiece to the side port of the valve so that the valve is oriented horizontally, and the saliva trap of the mouthpiece is pointed downward.
- Instruct the subject to try on the assembly. Adjust the straps so that the mouthpiece fits the subject comfortably. Make sure there are no leaks between the mouthpiece and the valve or around the mouthpiece.

The gas analyzer must warm up for at least 15 minutes.

Note: For increased accuracy, users must complete the flow Head Calibration procedure. Please see Appendix I for directions on how to perform this calibration. The calibration of the 1000L flow head requires a 3L Calibration Syringe.

Load a PreSaved flow Head Calibration (*.iwxfcd) File

Note: *This procedure is used once a calibration curve has been generated using the Spirometer Calibration directions in Appendix I.*

All of the following directions will be prompted by the software. Follow the directions as they pop up on the LabScribe software.

1. Load the lab settings file you wish to perform as stated in the "Start the Software" section (Figure HE-4-S7).
2. Assemble the spirometer, flow head, tubing, mixing chamber and calibration syringe as shown in Appendix I or in the SpirometerCalibration directions.
3. Click the Setup button shown in the left side window. Follow the directions as prompted by the (Figure HE-4-S8). The Online Setup Dialog window will open
    - Enter your subject's information or Load a subject from a previously saved file.
    - Click "Settings" to change any parameters you wish to view (Figure HE-4-S9).

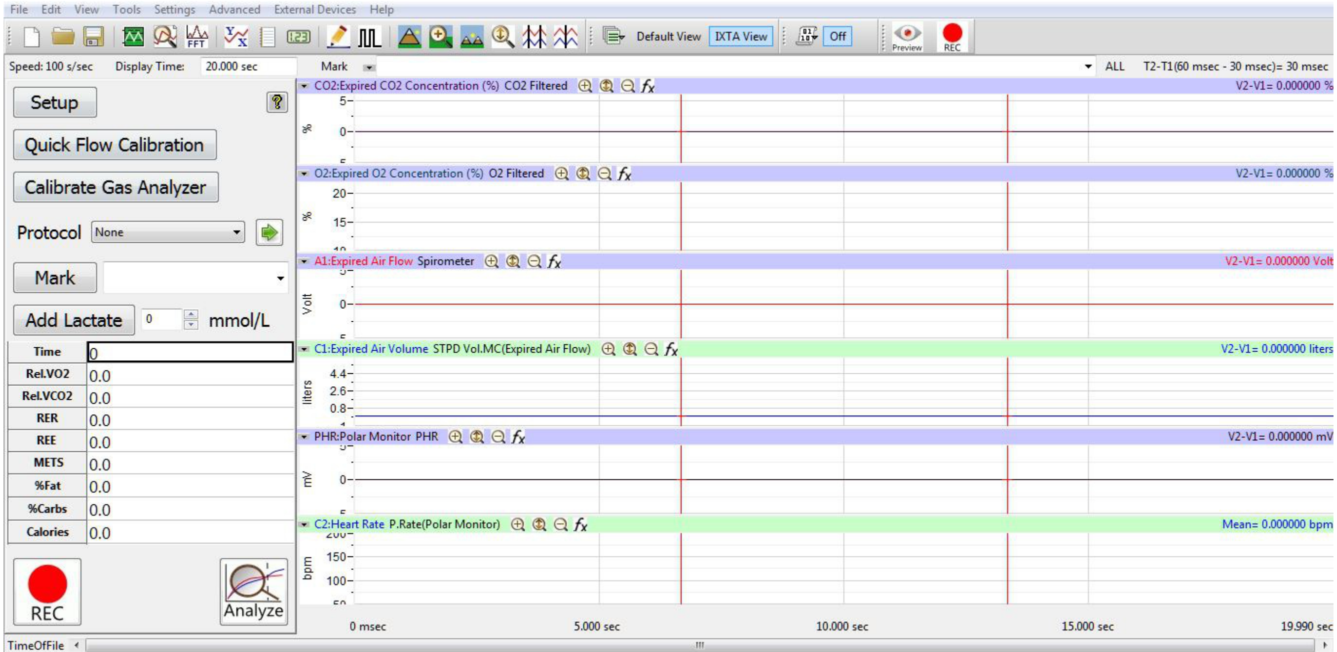


Figure HE-4-S7: Initial screen for starting a Fitness Assessment test. Follow the directions as prompted by the buttons on the left side of the window.

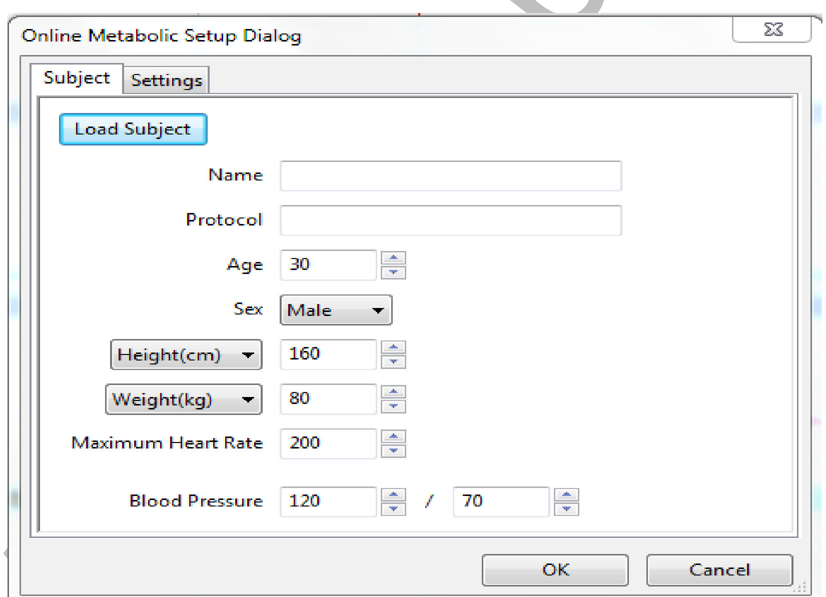


Figure HE-4-S8: Online Metabolic Setup Dialog window.

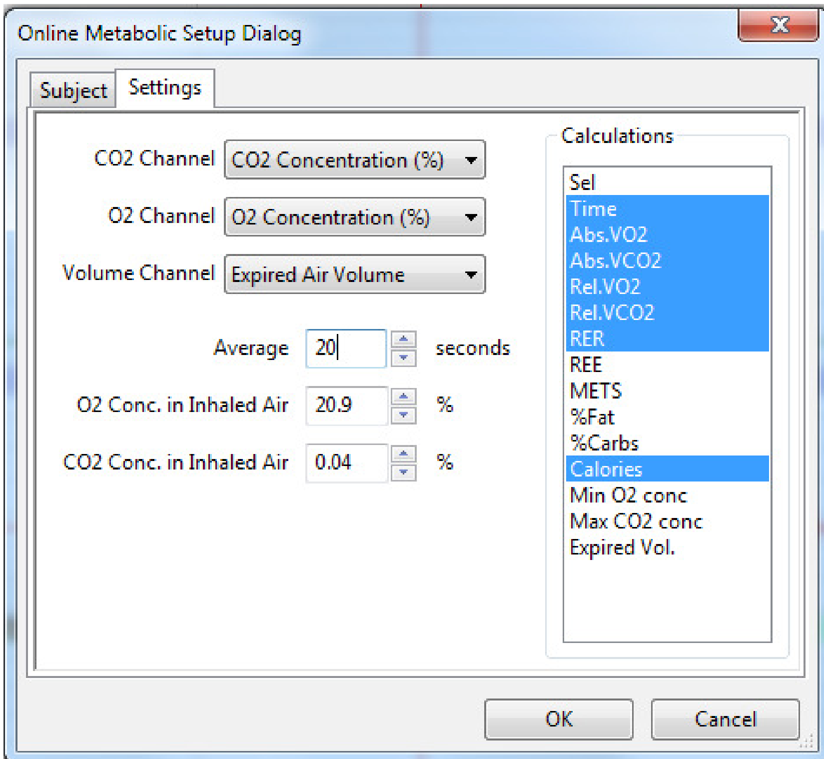


Figure HE-4-S9: Settings dialog of the Online Metabolic Setup window.

4. Perform the Quick Flow Calibration by clicking the button and following the prompted directions (Figure HE-4-S10).
   - When you click "Load", you will be prompted to load the .iwxfcd file created when you performed the full flow head calibration.

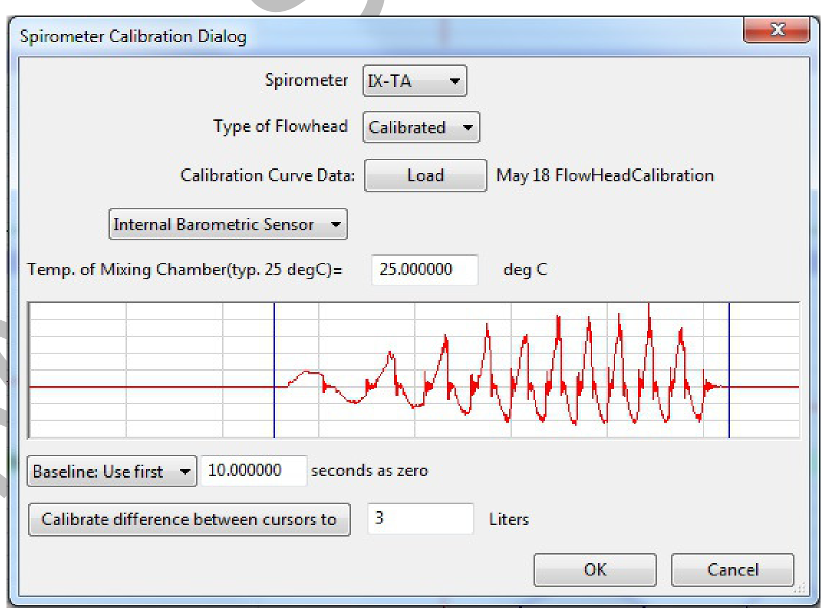


Figure HE-4-S10: Spirometer Calibration dialog window.

5. Select Save As in the File menu, type a name for the file. Click on the Save to save the data file.

Calibrating the iWire-GA Gas Analyzer

Note: *Warm up the gas analyzer for at least 15 minutes prior to use. Make sure the calibration gas tank is located close to the gas analyzer.*

This procedure will calibrate both the O_2 and CO_2 channels**.**

Connect the gas sample tubing of the A-CAL-150 Calibration Kit (Figure HE-4-S11) to the Luer-Lock connector on the output of the regulator.

Figure HE-4-S11 Calibration Kit (A-CAL-150).

1. Click the Calibrate Gas Analyzer button. Click Perform Quick Software Gas Calibration.
2. Follow the directions as prompted. Room air will be sampled for 10 seconds. Calibration gas will be sampled for 15 seconds.
3. If necessary, move the cursors into correct position (Figure HE-4-S12).

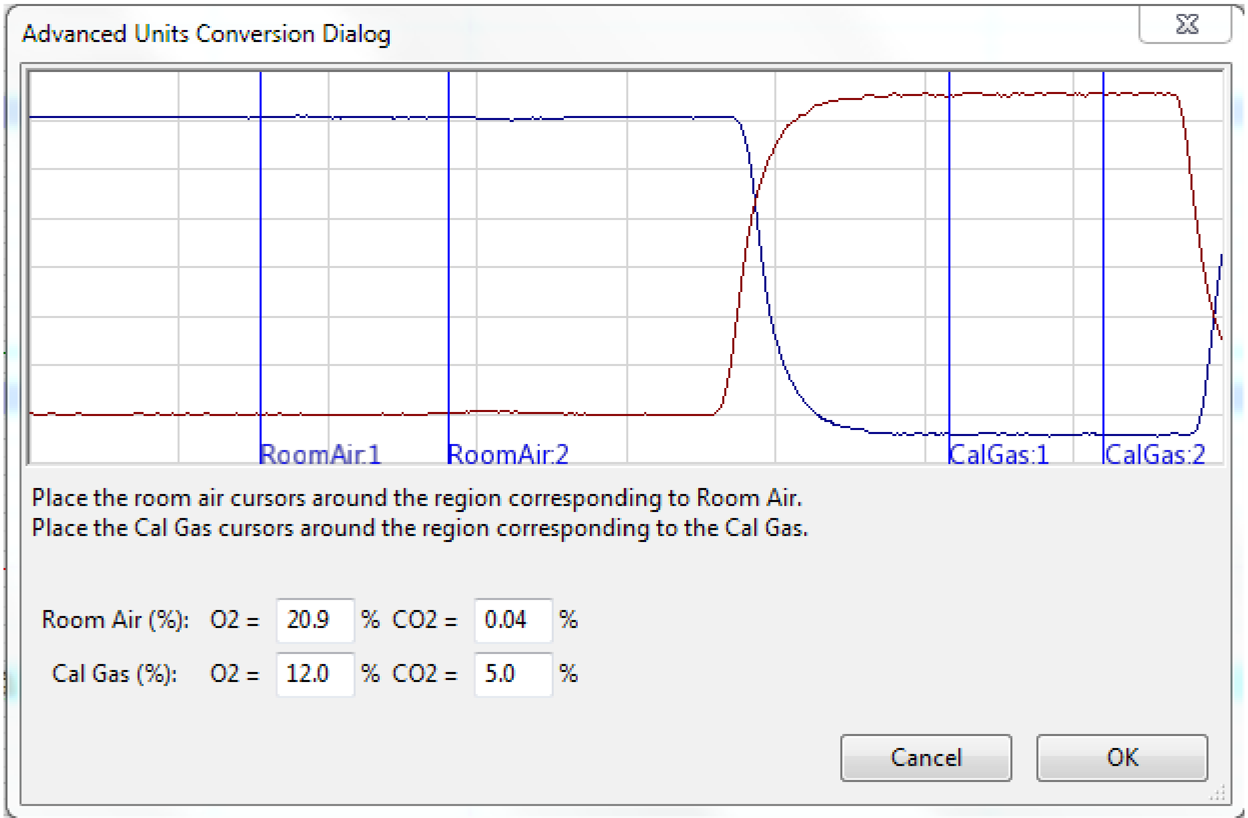


Figure HE-10 -S12: Advanced units conversion dialog for room air and calibration gas.

Appendix I: Initial Spirometer flow head Calibration

For accuracy of measurements, users must include this calibration procedure as part of the Exercise Physiology Lab protocol.

It is suggested that this procedure be followed at the beginning of every term and when using a new flow head-spirometer combination.

Note: *This calibration protocol precedes the actual calibration of the GA-200 or GA-300 gas analyzer. You will not need the gas analyzer at this time.*

Note: *Whenever you will be using a different flow head, you will need to repeat this calibration procedure from the beginning by loading a new Spirometer Calibration settings file.*

1. Open the LabScribe software.
2. Click Settings - Human Exercise-iWireGA. Choose SpirometerCalibration to launch the calibration settings file.
3. Assemble the flow head, tubing, mixing chamber and calibration syringe.
4. Plug the tubing into the internal spirometer channel A1.
    - Connect the flow head to the IXTA using the flow head tubing, making sure that the ribbed side of the tubing connects the red marked port on the flow head to the red marked port on the spirometer (Figure HE-4-S13).
    - Connect the smooth side of the tubing to the other ports.
5. Connect end of the1000L flow head with the red marked onto white flange of the mixing chamber. Make sure the tubing is in an upright direction (Figure HE-4-S14).

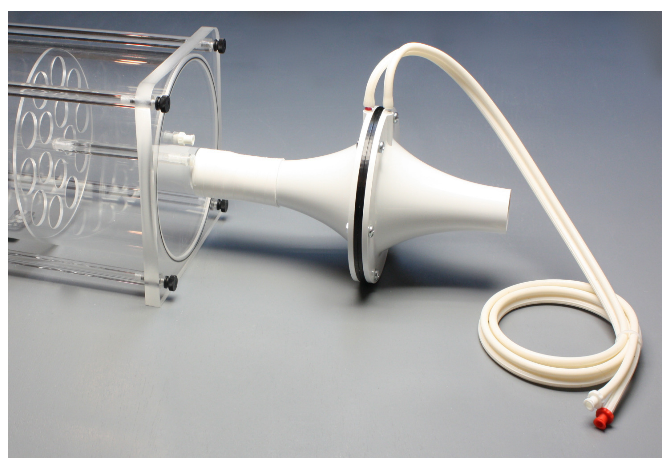



Figure HE-4-S13: The 1000L flow head and Figure HE-4-S14: The 1000L flow head attached to the mixing chamber showing the tubing in an upright position and the red port facing the mixing chamber.

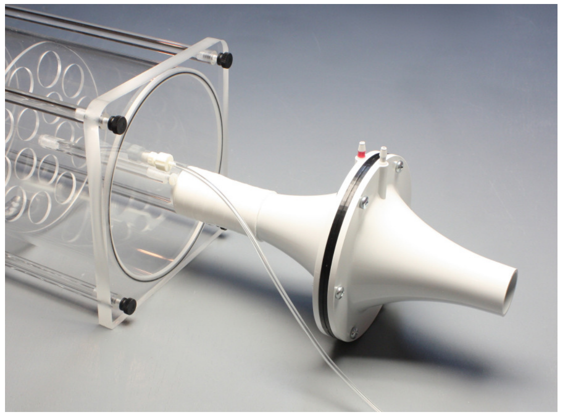


Figure HE-4-S15: 1000L flow head connected to the mixing chamber, showing the Nafion tubing connected to the outlet sampling port near the flow head.

Note: *Make sure the red port on the flow head faces into the mixing chamber.*

6. Connect one end of the smooth bore tubing to the 3L calibration syringe as shown in Figure HE-4-S16).
7. Connect the other end of the smooth bore tubing to the mixing chamber, opposite the flow head (Figure HE-4-S17).

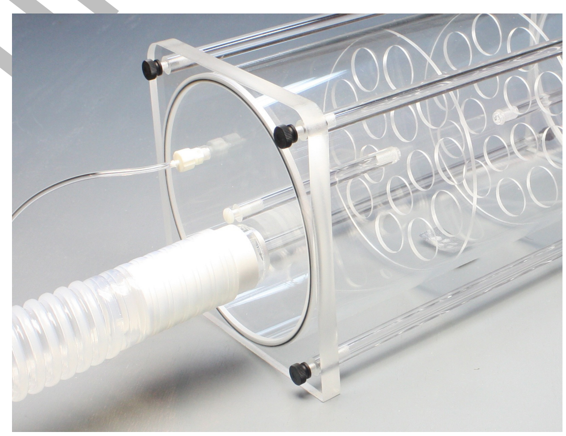


Figure HE-4-S16: 3 liter calibration syringe connected to the smooth bore tubing and Figure HE-4-S17: The smooth bore tubing connected to the mixing chamber.

8. If also setting up the gas analyzer at this time:
    - Connect the braided Nafion tubing to the filter on the gas analyzer and to the flow head side of the mixing chamber. Make sure the braided end is connected to the filter (Figure HE-4-S15).
    - Connect the thin flexible tubing from the outlet of the gas analyzer to the port next to the smooth bore tubing on the opposite side of the mixing chamber.

9. If not using the gas analyzer at this time, connect the flexible tubing from the port on one side of the mixing chamber to the port on the other. This ensures there is no air leaking from the chamber.
10. Pull the plunger on the 3L Calibration Syringe all the way out until it stops.
11. Click the Record button.
12. Wait for at least 10 seconds of recording so that there is no flow of air moving through the syringe.
13. Push the plunger in all the way until it stops. Pull the plunger out all the way until it stops.
14. Repeat the procedure in Step 13, for at least 50 repetitions, varying the speed and force on the plunger. Make sure to pause between strokes.
15. The faster the speed of the stroke, the higher the flow through the calibration syringe.

***Note:** Ideally the flow head calibration recording should span air flow values to include the minimum to maximum flow levels for the particular experiment being conducted.*

16. After at least 50 repetitions have been performed, wait at least 5 seconds after the final repetition and then click Stop.
17. Select Save As in the File menu, type a name for the file.
18. Click on the Save button to save the raw data for generation of a flow head calibration *.iwxfcd file.
19. Click AutoScale on the Air flow channel.
20. Use the Display Time icons to adjust the Display Time of the Main window to show the complete calibration data (Figure HE-4-S18).
21. Click the Double Cursor icon so that two cursors appear on the Main window.

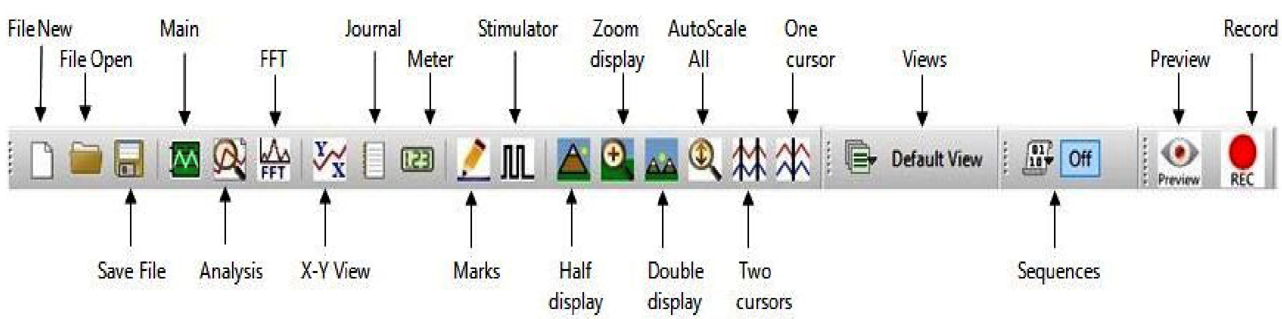


Figure HE-4-S18: The LabScribe toolbar.

22. Click Advanced on the main toolbar. Then click Metabolic, and Calibrate flow head (Figure HE-4-S19).
23. Place the two vertical cursors so that:

- The left-hand most cursor is on the flat line prior to the start of the calibration data. Make sure the cursor is at the beginning of the 10 second baseline.
- The right-hand most cursor is on the flat line after the final calibration stroke (Figure HE-4-S20).

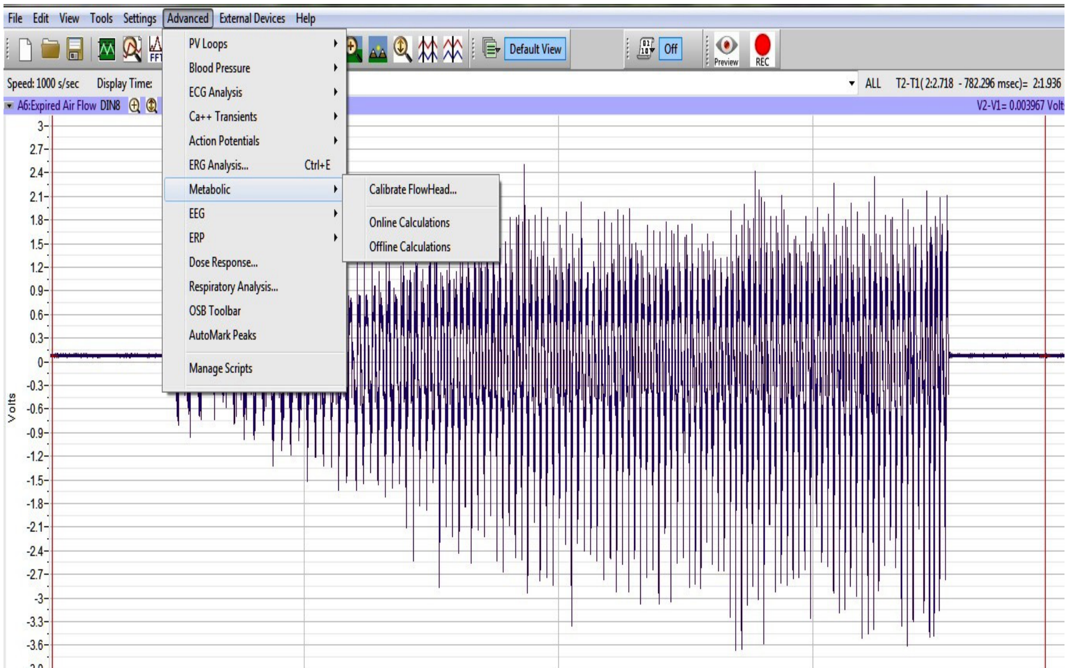


Figure HE-4-S20: Calibrate flow head dialog window.

24. In the new window that opens (Figure HE-4-S22), enter these values:
    - flow channel = Expired Air flow
    - Baseline = Use the first 10 seconds as zero
    - Calibrate difference between cursors to 3 L.
25. Click the Calibrate the difference between cursors to button. This will generate the curve as shown above.
26. A new window will open prompting you to Save your file as an *.iwxfcd flow head calibration file. Name your file and click Save.
27. Click OK.

Note: *At this point, a raw calibration data file (*.iwxdata) and a flow head calibration file (*.iwxfcd) have been generated.*

28. Exit LabScribe or open a Human Exercise lab settings file.

Note: *Once a saved *.iwxfcd file is loaded, a simple 5-10 stroke calibration procedure can be used to update the file for immediate use.*

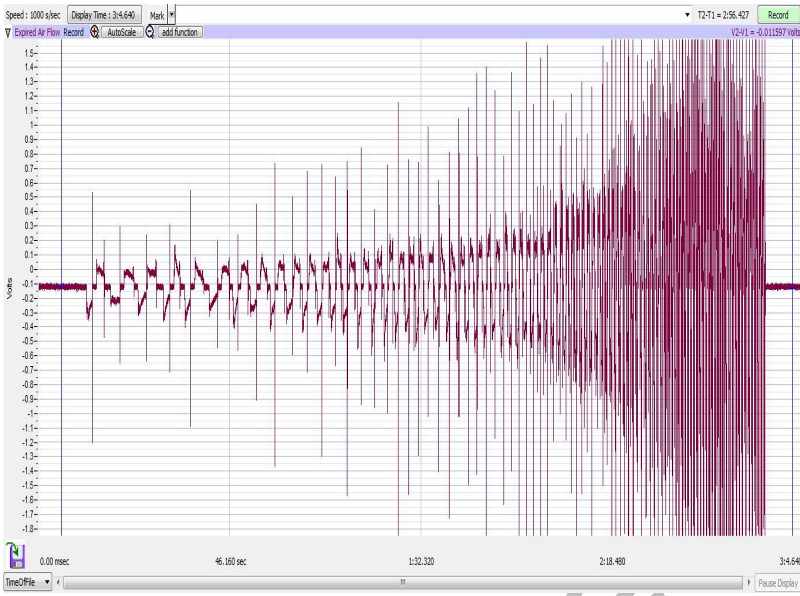


Figure HE-4-S21 The calibration recording showing the vertical cursors in the correct position for generating a calibration curve. Note – the recording you generate should look similar to this.

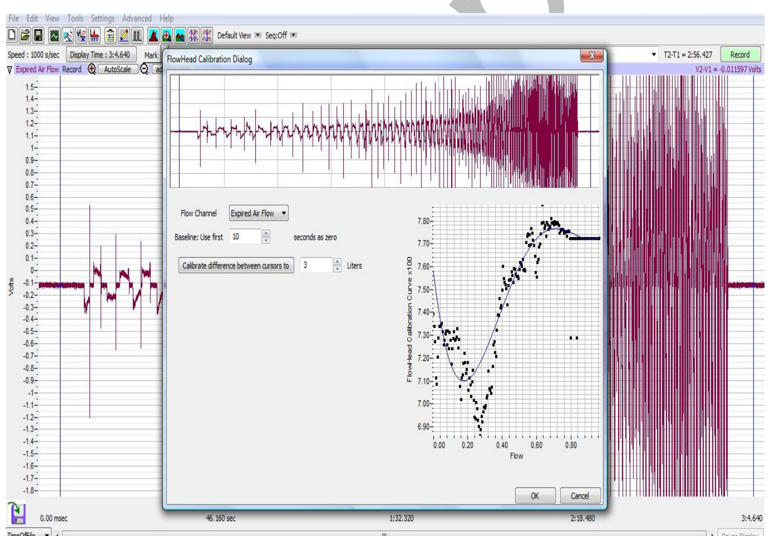


Figure HE-4-S22: Calibration syringe data.

Experiment HE-4: Respiratory Exchange Ratio (RER)

Before Starting

1. Read the procedures for the experiment completely before beginning the experiment. Have a good understanding of how to perform the experiment before making recordings.
2. It is important that the subject is healthy and has no history of respiratory or cardiovascular problems.
3. Allow the spirometer to warm up for 15 minutes before recording for the first time.
4. Determine if the airflow tubes between the flow head to the spirometer amplifier are attached to the proper inlets on each device.
    - Since this test does not need to be recorded, click on the Save to Disk button in the lower left corner of the Main window. If LabScribe is in Preview mode, there will be a red X across the Save to Disk button.
    - Click on the Preview button.

Note: *If the user clicks the Preview button and an error window appears on the Main window indicating the iWorx hardware cannot be found, make sure the iWorx unit is turned on and connected to the USB port of the computer. Then, click on the OK button in the error window. Pull down the LabScribe Tools menu, select the Find Hardware function, and follow the directions on the Find Hardware dialogue window.*

- Have the subject inhale and exhale through the mask 2 or 3 times while the complete spirometry circuit is assembled.
- Click on the AutoScale button at the upper margin of the Expired Air Flow and Lung Volume channels.
- If the proper end of the flow head is attached to the outlet of the mixing chamber, the traces on the Air Flow and Lung Volume channels will go up when the subject exhales.
- If the traces on these channels go down during exhalation, remove the flow head from the outlet of the mixing chamber and place the other end of the flow head on the outlet of the mixing chamber.
- Click on the Stop button.

5. Click on the Save to Disk button, in the lower left corner of the Main window, to change LabScribe from Preview mode to Record mode. If LabScribe is in Record mode, there will be a green arrow on the Save to Disk button.

Set Up the Online Metabolic Calculations Module

Note: This should be completed during the setup portion of lab and should open automatically. If not:

1. Pull down the Advanced menu and select Metabolic.
2. Select Mixing Chamber: Online Calculations from the submenu to open the Online Metabolic Calculations Dialog window (Figure HE-4-L1).
3. Click the down arrow to the left of the dialog window (Metabolic).
   - Click Setup.
   - Make sure the correct channels are selected for CO_2, O_2, and Volume.
   - Select the time for averaging - generally between 10 and 30 seconds.
   - Enter the weight of the subject.
   - Set the O_2 and CO_2 concentrations for inhaled air.
   - Click OK.
4. The Online Metabolic Calculations are now set to record real time parameters during the lab experiments.

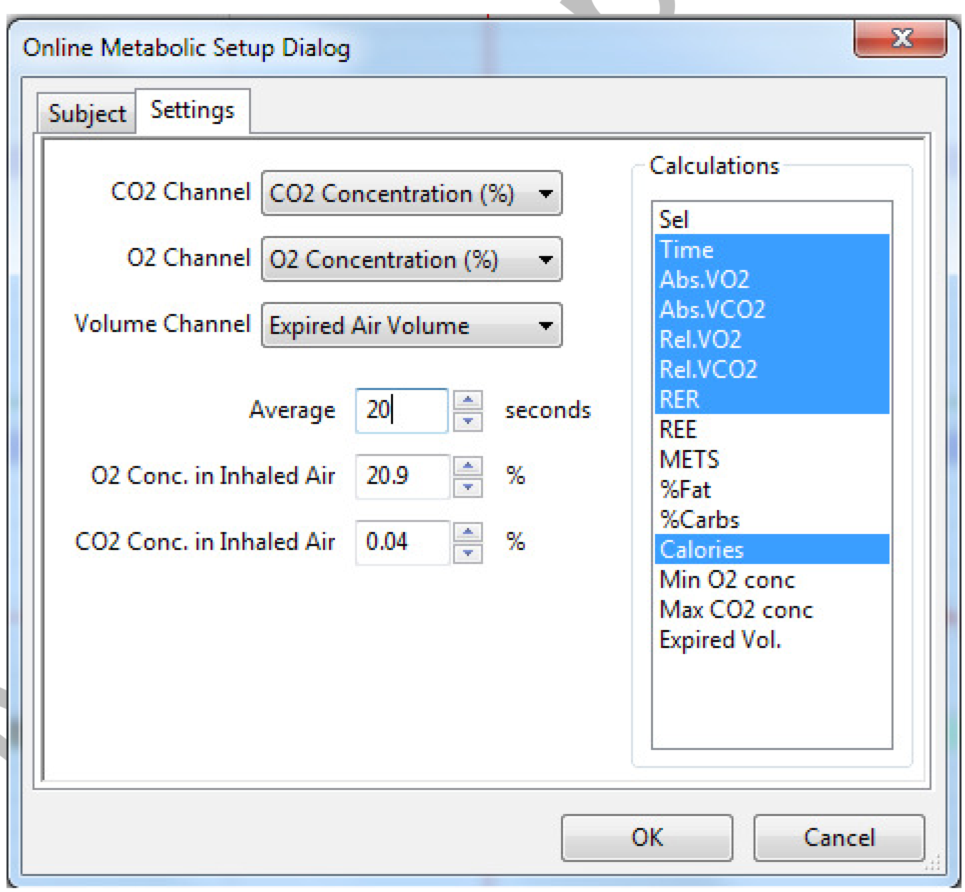


Figure HE-4-L1: Online Metabolic Calculations dialog window.

Exercise 1: VCO_2, VO_2, and RER at Rest

Aim: To determine the effect of breathing at rest on VCO_2, VO_2, and RER.

Procedure

1. Instruct the subject to sit quietly, become accustomed to breathing through the spirometry equipment, and breathe normally before any recordings are made.
2. Once the subject and recording equipment are all prepared, disconnect the smooth-bore tubing from the mixing chamber to ensure that no air is entering the system at this time.

Note: *So that the LabScribe software can zero the Lung Volume channel, no air can be moving through the system during the first ten seconds of the recording.*

3. Type <Subject's Name> baseline in the Mark box that is to the right of the Mark button.
4. Click on the Record button. After waiting ten seconds for the Lung Volume channel to zero, the smooth bore tubing should be reconnected to the mixing chamber. Make sure that the tubing is firmly attached to the chamber.
5. Click the AutoScale buttons on all channels.
6. On the Expired CO2 Concentration (%) channel, notice that the CO_2 concentration increases in the first few minutes of the recording and then reaches a near-steady level.
   - The time that it takes the chamber to be filled with expired air and reach a near-steady level of carbon dioxide is dependent on the tidal volume and respiration rate of the subject and the volume of the mixing chamber. It will take longer to fill the chamber if the subject's respiration rate and tidal volume are low, or the chamber is large.
   - Every breath exhaled into the mixing chamber pushes a matching volume of expired air out of the mixing chamber.
   - Record baseline data, while the mixing chamber air is replaced with the subject's expired air, for approximately 5-10 minutes prior to beginning any experiments.
7. On the Expired O2 Concentration (%) channel, notice that the O_2 concentration decreases in the first few minutes of the recording and then stays a near-steady level. As pointed out in the previous step, the size of the mixing chamber, the tidal volume, and respiration rate of the subject, determine the time it takes for the concentration of oxygen in expired air to reach that near-steady level.
8. On the Expired Air Volume channel, the Volume-MC function converts the data from the Air Flow channel to the volumes of expired air at the STPD. Notice that the recorded volume increases in a ramp-like manner with each breath.
9. Continue to record until at least 5 minutes of data are recorded while the concentrations of oxygen and carbon dioxide in expired air are at a steady level. Once the appropriate duration of data is recorded, click Stop to halt the recording. Your recording should be similar to the data displayed in Figure HE-4-L2.

10. Select Save As in the File menu, type a name for the file. Choose a destination on the computer in which to save the file, like your lab group folder. Designate the file type as *.iwxdata. Click on the Save button to save the data file.

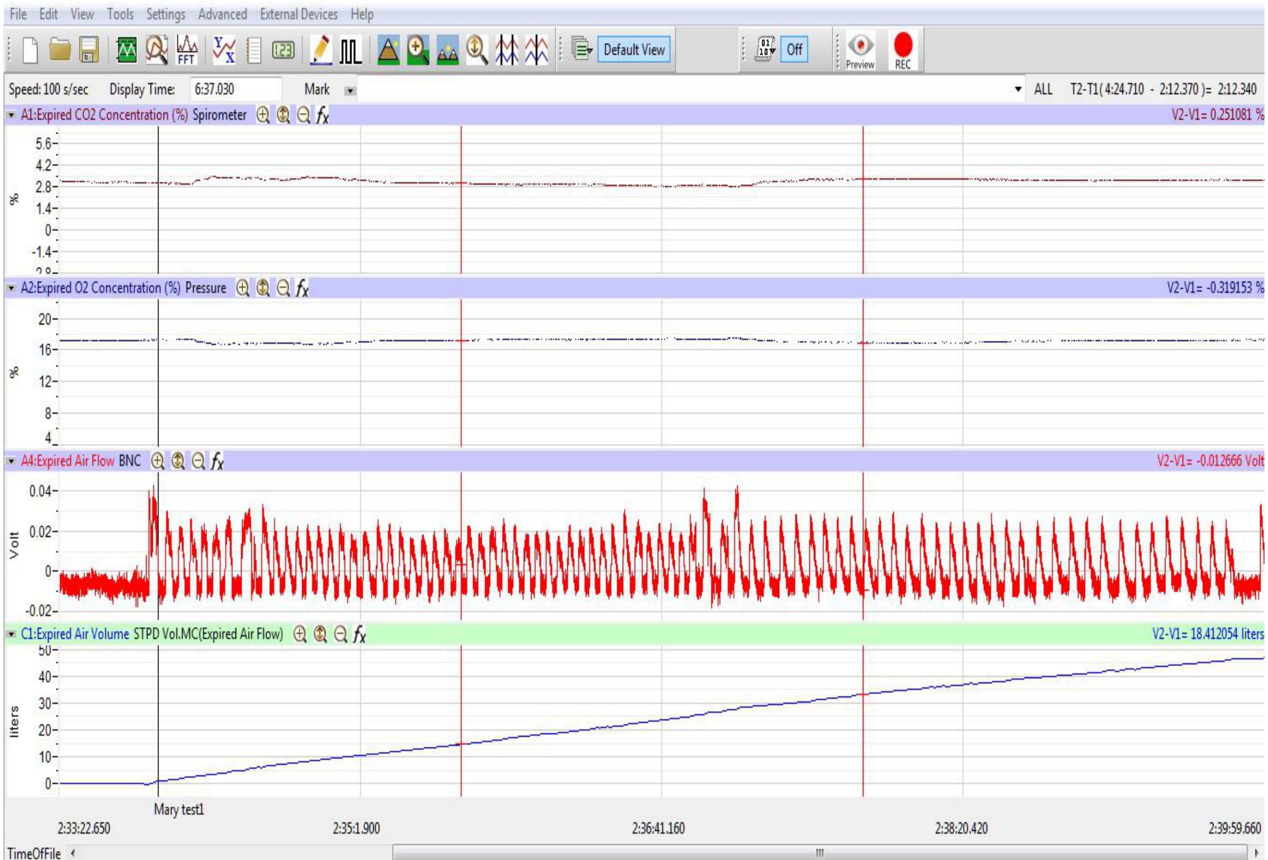


Figure HE-4-L2: Gas concentrations and volumes of a standing subject displayed on the Main window. Concentrations of gases reach a steady state after the mixing chamber is filled.

Data Analysis

1. Display the complete data recording in the Main window. Use the Display Time icons to adjust the Display Time of the Main window to show the complete recording on the Main window.
2. Select and display at least a 60-second section of the recording while the oxygen and carbon dioxide concentrations were at a steady level on the Main window. Select the 60-second section of the recording by:
   - Placing the cursors on either side of the 60-second section of data; and,
   - Clicking the Zoom between Cursors button on the LabScribe toolbar to expand the selected section of data to the width of the Main window.

Calculate and Plot Metabolic Parameters

Values for VO_2, VCO_2, RER, TV, and other parameters (Table HE-4-L1) from the segments of the test can be calculated automatically by using the Metabolic Calculations window.

1. To use the Metabolic Calculations window, pull down the Advanced menu and select Metabolic. Select Mixing Chamber: Offline Calculations from the submenu to open the Metabolic Calculations Dialog window.
2. On the left side of the Metabolic Calculations window:
    - Pull down the CO2, O2, Volume, Heart Rate, and Energy Channel menus to select the channels on which the CO_2 and O_2 concentrations, lung volumes, heart rates, and workload were recorded.
    - When analyzed, the data file will be divided into time segments. The average of each parameter in each segment will be reported in the data table on the Metabolic Calculations window. Enter the time (in secs) in the Average box to select the time length of each segment.
    - In the O_2 and CO_2 Concentrations in Inhaled Air boxes, enter the concentrations of oxygen and carbon dioxide in the inhaled air, which is room air in most tests.
3. Click on the Calculate button on the left side of the Metabolic Calculations Dialog window to calculate the average value of each parameter listed in the table for each time segment of the recorded data, and to plot the selected parameters against each other in the plot panel (Figure HE-4-L3).
4. In the lower left corner of the plot panel, click on the arrow to open the pull-down menu listing the types of plots (Table HE-4-L2) that can be made with the metabolic parameters calculated by this analytical tool. Select the plot to be displayed in the plot panel when the calculations are performed.

Table HE-4-L1: List of Parameters Calculated on the Mixing Chamber Offline Metabolic Window

Term	Parameter	Description	Units
Abs.VO_2	Absolute VO_2	Volume of oxygen (O_2) consumed/minute	Liters/minute
Abs.VCO_2	Absolute VCO_2	Volume of carbon dioxide (CO_2) produced per minute	Liters/minute
Rel.VO_2	Relative VO_2	Volume of O_2 consumed per kg body weight per minute	ml/kg/minute
Rel.VCO_2	Relative VCO_2	Volume of CO_2 produced per kg body weight per minute	ml/kg/minute
RER	Respiratory Exchange Ratio	Ratio of VCO_2/VO_2	None
REE	Resting Energy Expenditure	5.46 (Absolute VO_2) + 1.75 (Absolute VCO_2)	kcal/day
METS	Metabolic Equivalent of Task	1 MET = 3.5ml O_2/kg/min or 1kcal/kg/hr	MET
O_2 Min.	O2 Minimum - exhalation	Minimum concentration of O_2 recorded during test period	Percentage
CO_2 Max.	CO2 Maximum - exhalation	Maximum concentration of CO_2 recorded during test period	Percentage
VE	Expired Tidal Volume	Volume of air displaced during normal exhalation	Liters/breath
P	Power	Workload during the stages of the test	Watts
HR	Heart Rate	Number of beats in a minute - divide (60 sec/min) by the beat period (sec/breath)	Beats/minute

Table HE-4-L2: Plots Available on the Offline Metabolic Window.

	Available Plots										
Y-Axis Parameter 1	VO_2	VCO_2	V_e	V_e	HR	V_t	V_e	HR	VO_2	V_e/VO_2	RER
Y-Axis Parameter 2	VCO_2				VCO_2			VO_2/HR	VCO_2	V_e/VCO_2	
Y-Axis Parameter 3	RER										
X-Axis Parameter	Time	VO_2	VO_2	VCO_2	VO_2	V_e	Watts	Watts	Watts	Watts	Watts

Exercise 2: Effect of Hyperventilation on VCO_2, VO_2, and RER

Aim: To measure the effect of deep breathing on VCO_2, VO_2, and RER during and after the period of hyperventilation.

Procedure

1. Use the same procedures used in Exercise 1 to record the lung volumes from the subject while the gas concentrations are reaching a steady state, while the subject is hyperventilating for a minute, and while the subject is recovering from hyperventilation.
2. Mark the recording with comments that indicate the name of the subject and the beginning of the three periods being recorded.
3. The subject should breathe normally as his or her expired air is filling the mixing chamber. During this period of time, the concentrations of oxygen and carbon dioxide in the chamber are nearing a steady level. Once the concentrations of oxygen and carbon dioxide have reached steady levels, the subject should begin hyperventilating so that his or her inhalation volume at least 3 times the resting tidal volume (Figure HE-4-L4). Mark the recording with a comment to indicate the beginning of the period of hyperventilation.
4. The subject should hyperventilate for at least one minute. If the subject cannot hyperventilate for one minute because he or she is feeling dizzy, the subject should return to breathing normally. The subject does not need to complete a full minute of hyperventilation. The volumes recorded during hyperventilation can be prorated to provide minute volumes.
5. After the period of hyperventilation, the subject should return to breathing normally. Mark the recording with a comment to indicate the beginning of the recovery period.

Data Analysis

1. Use the same procedures used in Exercise 1 to determine the oxygen consumed (VO_2), carbon dioxide produced (VCO_2), and respiratory exchange ratio (RER) during the hyperventilation and recovery from hyperventilation when the gas concentrations were at steady levels.
2. If the concentrations of oxygen and carbon dioxide were at a steady level for less than a minute, prorate volumes to minute volumes. For example, if the oxygen and carbon dioxide concentrations reached a steady level for 30 seconds during hyperventilation, the measured volumes are converted to minute volumes by multiplying the 30-second values by 2.
3. Record the values for the mean CO_2 and O_2 concentrations in expired air, the minute volume of expired air at STPD, the VCO_2, and the VO_2 for the periods of steady gas concentrations during hyperventilation and recovery from hyperventilation on Table HE-4-L3.
4. Calculate the Respiratory Exchange Ratio (RER) for the period when the subject was hyperventilating by dividing the value for VCO_2 by the value for VO_2 for the period. Record the value of the RER in Table HE-4-L3. Repeat the RER calculation for recovery period after hyperventilation.

Table HE-4-L3: VCO_2, VO_2 and the Respiratory Exchange Ratio (RER) of a Subject at Rest, Hyperventilating, and Recovering from Exercise.

Environmental Conditions	Experimental Periods	Concentration (%) in Expired Air		Expired Air Volume (STPD)	Volume of CO_2 Produced (VCO_2)	Volume of O_2 Consumed(VO_2)	RER
		CO_2	O_2				
Temperature (^oC)	Resting [Gas] Steady						
	Hyperventilation [Gas] Steady						
Barometric Pressure (mmHg)	1st Minute After Hyperventilation						
	First Minute After Exercise						
Relative Humidity (%)	Second Minute After Exercise						
	Third Minute After Exercise						

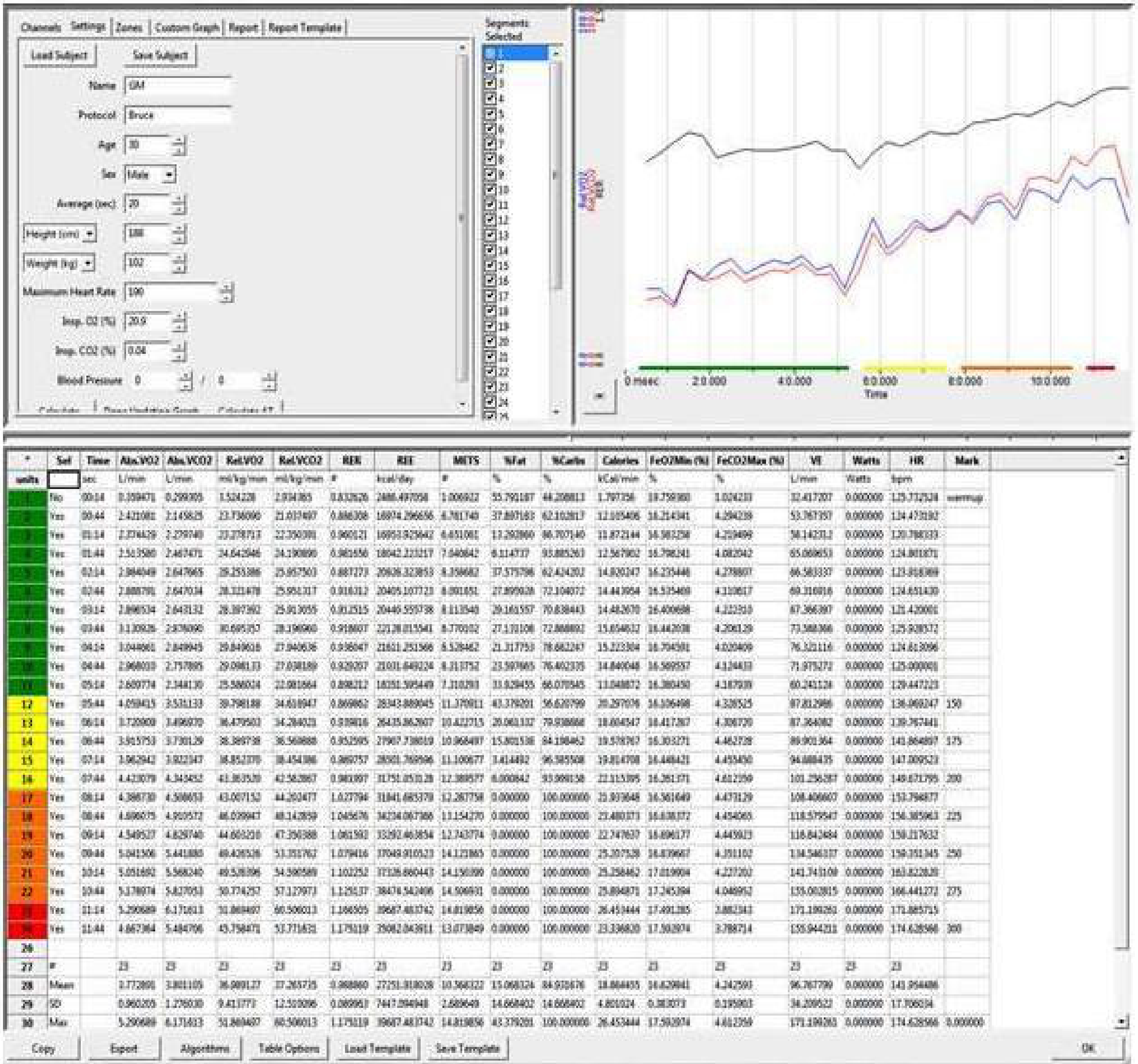


Figure HE-4-L3: The metabolic parameters, and plots of VO_2, VCO_2, and RER vs. Time, displayed in the Metabolic Calculations window used offline to analyze data collected during an aerobic fitness test. Notice that the VO_2 and VCO_2 values increase quickly as the subject performs more strenuous segments of the test.

Exercise 3: Effect of Moderate Exercise on VCO_2, VO_2, and RER

Aim: To measure the effects of moderate exercise on VCO_2, VO_2, and RER during the recovery period after exercise.

Procedure

1. Use the same procedures used in Exercise 1 to record the lung volumes from the subject during the first, second, and third minutes of recovery from exercise.
2. Mark the recording with comments that indicate the name of the subject and the beginning of each minute being recorded.

Data Analysis

1. Use the same procedures used in Exercise 1 to determine the oxygen consumed (VO_2), carbon dioxide produced (VCO_2), and respiratory exchange ratio (RER) during the first, second, and third minutes of recovery.
2. Record the values for the mean CO_2 and O_2 concentrations in expired air, the minute volume of expired air at STPD, the VCO_2, and the VO_2 for each minute of recovery on Table HE-4-L3.
3. Calculate the Respiratory Exchange Ratio (RER) for each minute of recovery by dividing the value for VCO_2 by the value for VO_2 for that period. Record the values for RER in the data table.

Questions

1. During which experimental period was the subject's VCO_2 the highest? In which period was it the lowest?
2. During which period was the subject's VO_2 the highest? In which period was it the lowest?
3. During which period did the subject have the highest RER? In which period was the RER the lowest?
4. Evaluate the physical fitness of your subject. How does the level of your subject's physical fitness correlate to his or her RER at rest? While hyperventilating? While recovering from exercise?
5. Evaluate the diet of your subject. How does your subject's diet correlate to his or her RER at rest? While hyperventilating? While recovering from exercise?
6. How does your subject's level of physical fitness, diet, and RER correlate to those parameters from other members of the class?

Figure HE-4-L4: Recording of gas concentrations and lung volumes from a hyperventilating subject. Hyperventilation is followed by the recovery period.