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 SP-304 to warm up for 15 minutes before recording for the first time.
4. Determine if the airflow tubes between the flowhead 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 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 flowhead 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 flowhead from the outlet of the mixing chamber and place the other end of the flowhead 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: *Some users prefer to see the metabolic parameters as the software is recording them in real time. The Online Metabolic Module allows for real time viewing of these parameters.*

1. To use the Metabolic Calculations window, 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 CO2, O2, and Volume.
    - Select the time for averaging - generally between 10 and 30 seconds.
    - Enter the weight of the subject.
    - Set the O2 and CO2 concentrations for inhaled air.
    - Click OK.
4. The Online Metabolic Calculations are now set to record real time parameters during the lab experiments.

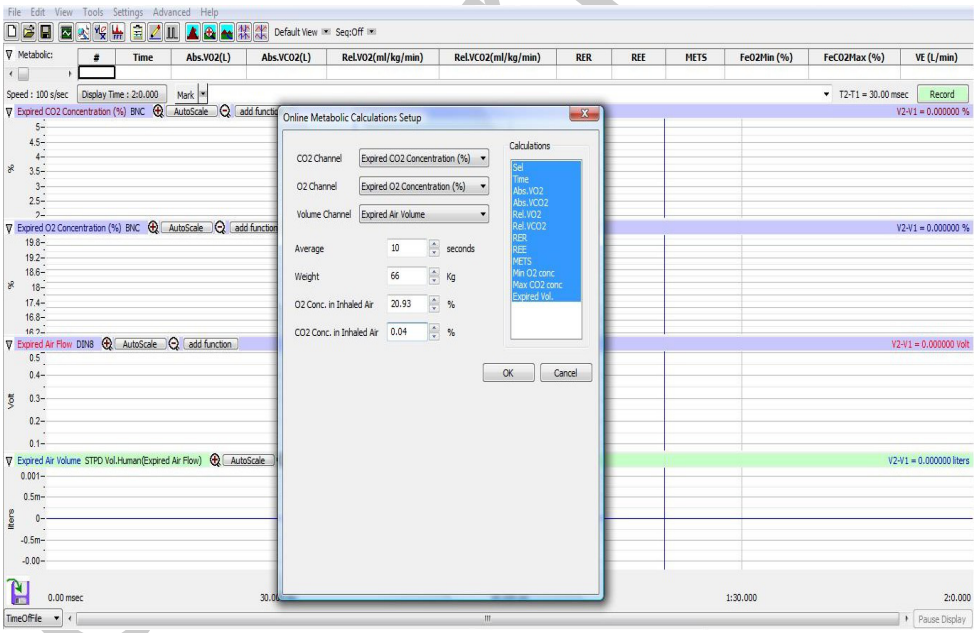


Figure HE-4-L1: Online Metabolic Calculations dialog window.

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. Remove the flowhead from the end of the outlet of the mixing chamber.
3. Type <Subject's Name> Inhalation at Rest 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 Expired Air Volume channel to zero, connect the proper end of the flowhead to the outlet of the mixing chamber. Press the Enter key on the keyboard to mark the recording.

Note: *The LabScribe software will zero the Lung Volume channel during the first ten seconds of recording. No air should be moving through the flowhead during this time.*

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.

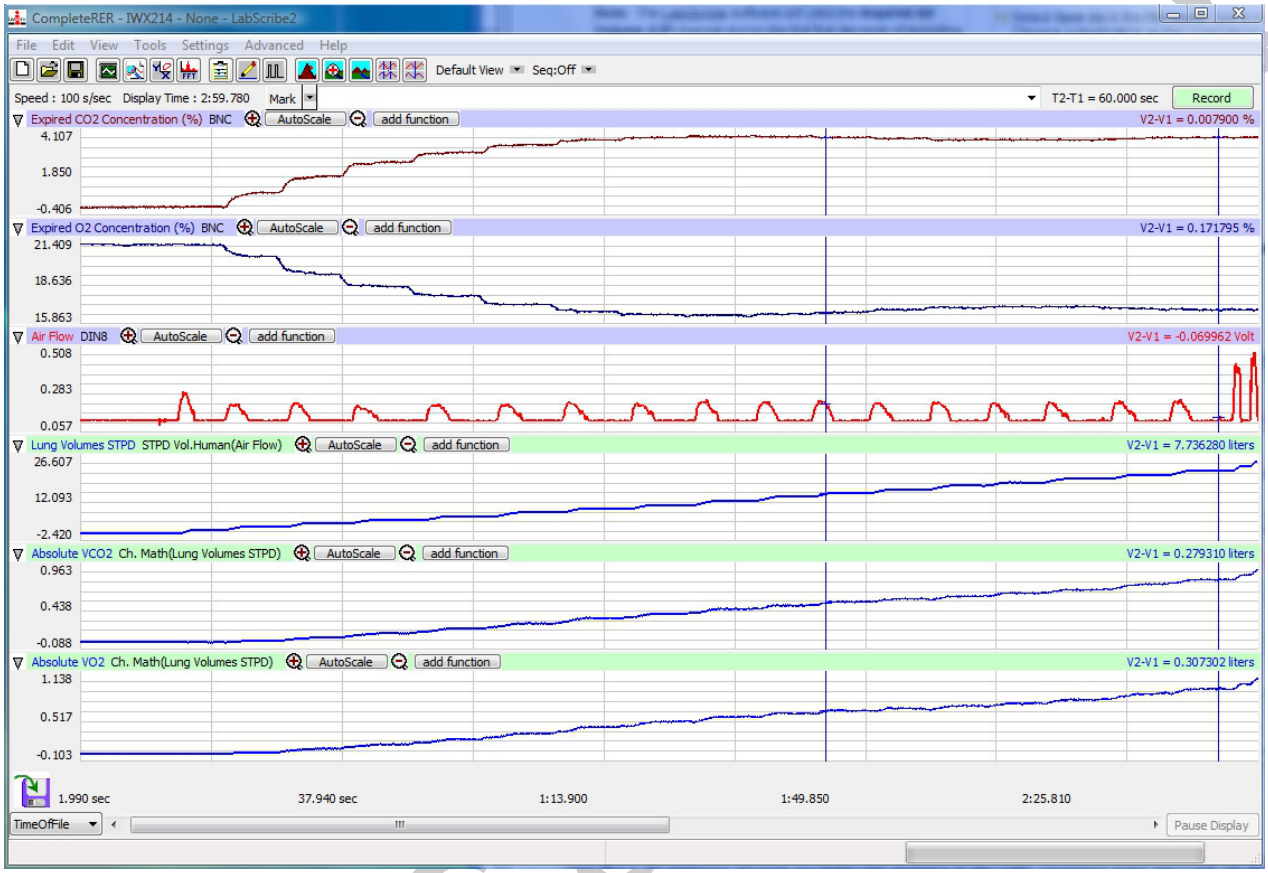


Figure HE-4-L2: Gas concentrations and volumes of a standing subject displayed on the Main window. Concentrations of gases reach a steady state after the mixing chamber is filled.

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.

Note: *The first time using the Advanced Metabolic Calculations will require the entry of a User Name and Serial Number. These were supplied when you received your equipment.*

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 (O2) consumed/minute	Liters/minute
Abs.VCO_2	Absolute VCO_2	Volume of carbon dioxide (CO2) produced per minute	Liters/minute
Rel.VO_2	Relative VO_2	Volume of O2 consumed per kg body weight per minute	ml/kg/minute
Rel.VCO_2	Relative VCO_2	Volume of CO2 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
TV	Tidal Volume	Volume of air displaced during a normal breath cycle - inhalation and exhalation	Liters/breath
RR	Respiratory Rate	Number of breaths per minute; (60 sec/min) divided by the (sec/breath)	Breaths/minute
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 O2 recorded during test period	Percentage
CO_2 Max.	CO2 Maximum - exhalation	Maximum concentration of CO2 recorded during test period	Percentage
VI	Inspired Tidal Volume	Volume of air displaced during normal inhalation	Liters/breath
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	Beats/minute

		(60 sec/min) by the beat period (sec/breath)	

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

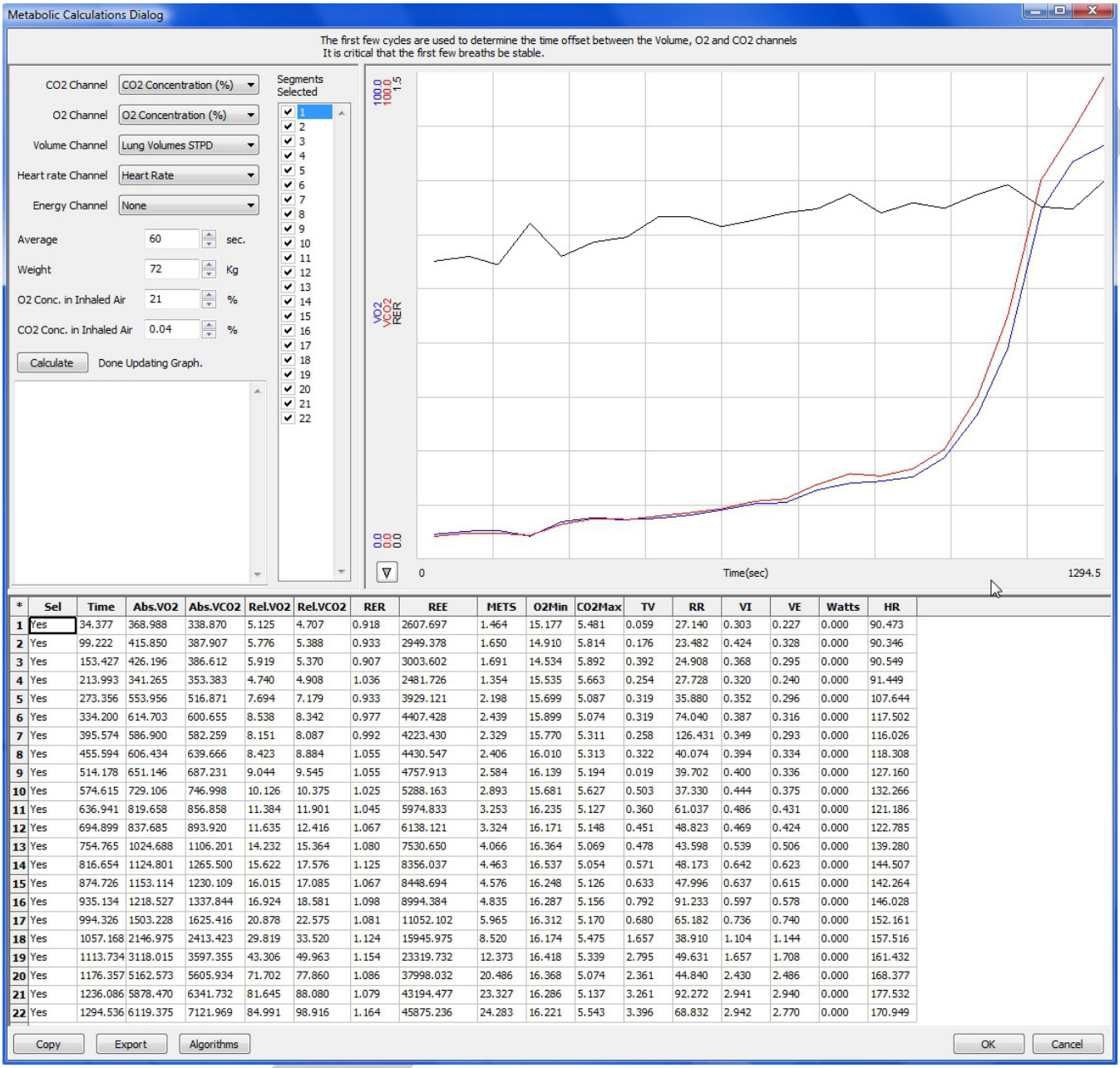
1. Use the same procedures used in Exercise 1 to record the lung volumes from the subject while the gas concentrations are reaching a steady state, while the subject is hyperventilating for a minute, and while the subject is recovering from hyperventilation.
2. Mark the recording with comments that indicate 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						



*	Sel	Time	Abs.VO2	Abs.VCO2	Rel.VO2	Rel.VCO2	RER	REE	METS	O2Min	CO2Max	TV	RR	VI	VE	Watts	HR
1	Yes	34.377	368.988	338.870	5.125	4.707	0.918	2607.697	1.464	15.177	5.481	0.059	27.140	0.303	0.227	0.000	90.473
2	Yes	99.222	415.850	387.907	5.776	5.388	0.933	2949.378	1.650	14.910	5.814	0.176	23.482	0.424	0.328	0.000	90.346
3	Yes	153.427	426.196	386.612	5.919	5.370	0.907	3003.602	1.691	14.534	5.892	0.392	24.908	0.368	0.295	0.000	90.549
4	Yes	213.993	341.265	353.383	4.740	4.908	1.036	2481.726	1.354	15.535	5.663	0.254	27.728	0.320	0.240	0.000	91.449
5	Yes	273.356	553.956	516.871	7.694	7.179	0.933	3929.121	2.198	15.699	5.087	0.319	35.880	0.352	0.296	0.000	107.644
6	Yes	334.200	614.703	600.655	8.538	8.342	0.977	4407.428	2.439	15.899	5.074	0.319	74.040	0.387	0.316	0.000	117.502
7	Yes	395.574	586.900	582.259	8.151	8.087	0.992	4223.430	2.329	15.770	5.311	0.258	126.431	0.349	0.293	0.000	116.026
8	Yes	455.594	606.434	639.666	8.423	8.884	1.055	4430.547	2.406	16.010	5.313	0.322	40.074	0.394	0.334	0.000	118.308
9	Yes	514.178	651.146	687.231	9.044	9.545	1.055	4757.913	2.584	16.139	5.194	0.019	39.702	0.400	0.336	0.000	127.160
10	Yes	574.615	729.106	746.998	10.126	10.375	1.025	5288.163	2.893	15.681	5.627	0.503	37.330	0.444	0.375	0.000	132.266
11	Yes	636.941	819.658	856.858	11.384	11.901	1.045	5974.833	3.253	16.235	5.127	0.360	61.037	0.486	0.431	0.000	121.186
12	Yes	694.899	837.685	893.920	11.635	12.416	1.067	6138.121	3.324	16.171	5.148	0.451	48.823	0.469	0.424	0.000	122.785
13	Yes	754.765	1024.688	1106.201	14.232	15.364	1.080	7530.650	4.066	16.364	5.069	0.478	43.598	0.539	0.506	0.000	139.280
14	Yes	816.654	1124.801	1265.500	15.622	17.576	1.125	8356.037	4.463	16.537	5.054	0.571	48.173	0.642	0.623	0.000	144.507
15	Yes	874.726	1153.114	1230.109	16.015	17.085	1.067	8448.694	4.576	16.248	5.126	0.633	47.996	0.637	0.615	0.000	142.264
16	Yes	935.134	1218.527	1337.844	16.924	18.581	1.098	8994.384	4.835	16.287	5.156	0.792	91.233	0.597	0.578	0.000	146.028
17	Yes	994.326	1503.228	1625.416	20.878	22.575	1.081	11052.102	5.965	16.312	5.170	0.680	65.182	0.736	0.740	0.000	152.161
18	Yes	1057.168	2146.975	2413.423	29.819	33.520	1.124	15945.975	8.520	16.174	5.475	1.657	38.910	1.104	1.144	0.000	157.516
19	Yes	1113.734	3118.015	3597.355	43.306	49.963	1.154	23319.732	12.373	16.418	5.339	2.795	49.631	1.657	1.708	0.000	161.432
20	Yes	1176.357	5162.573	5605.934	71.702	77.860	1.086	37998.032	20.486	16.368	5.074	2.361	44.840	2.430	2.486	0.000	168.377
21	Yes	1236.086	5878.470	6341.732	81.645	88.080	1.079	43194.477	23.327	16.286	5.137	3.261	92.272	2.941	2.940	0.000	177.532
22	Yes	1294.536	6119.375	7121.969	84.991	98.916	1.164	45875.236	24.283	16.221	5.543	3.396	68.832	2.942	2.770	0.000	170.949

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?

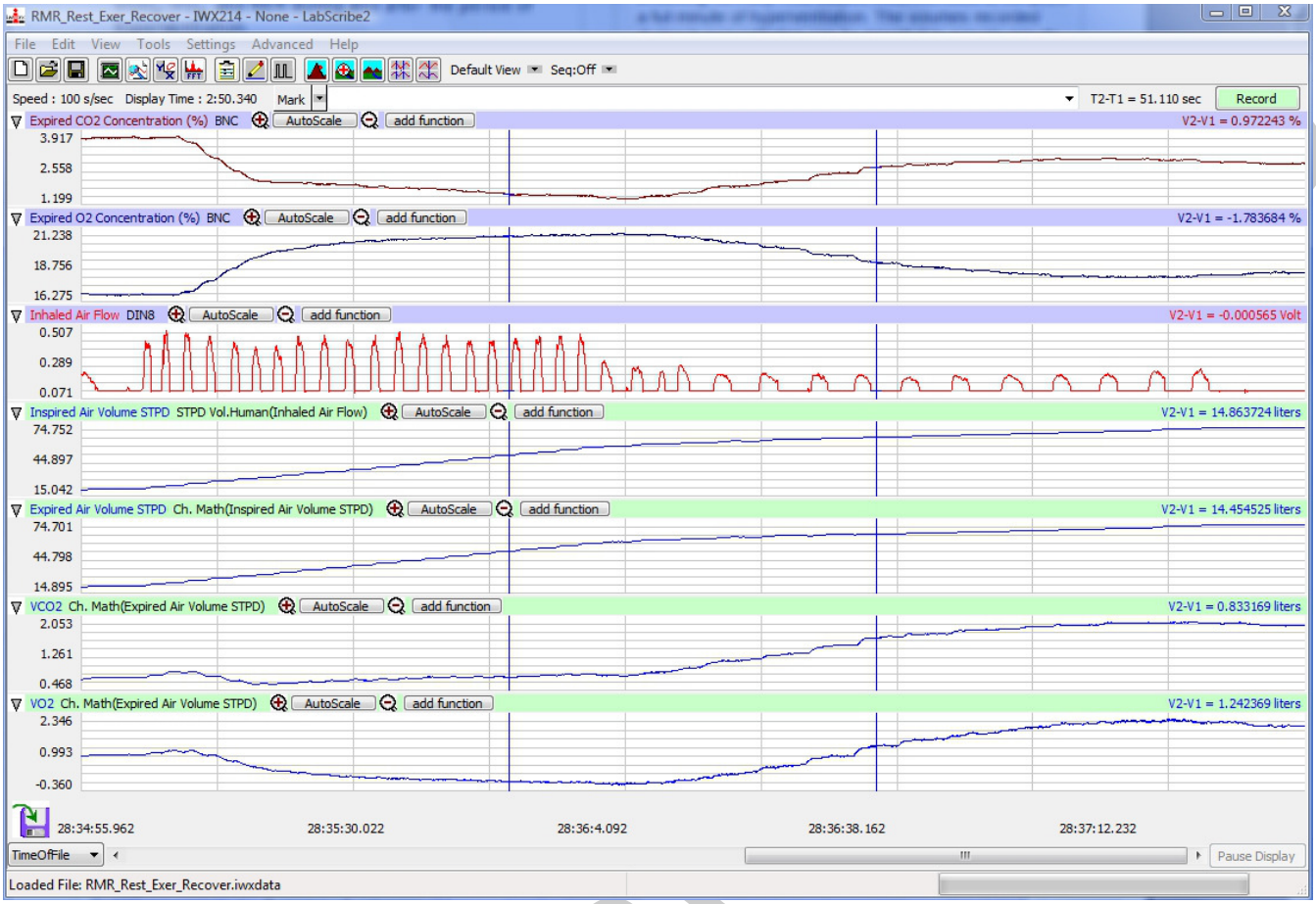


Figure HE-4-L4: Recording of gas concentrations and lung volumes from a hyperventilating subject. Hyperventilation is followed by the recovery period.