Experiment HE-10

Aerobic Fitness Testing

Note: The lab presented here is intended for evaluation purposes only. iWorx users should refer to the User Area on www.iworx.com for the most current versions of labs and LabScribe2 Software.
HE-10: Aerobic Fitness Testing

Background

**Fitness Factors**

Aerobic fitness is the ability to exercise continuously for extended periods without tiring. Also known as cardiovascular endurance, aerobic fitness is an important component in many endurance sports, like distance running, cycling, and rowing.

Aerobic fitness is dependent on the amount of oxygen that can be transported by the body to the muscles performing work. Factors that influence the amount of oxygen transported include:

- the amount of oxygen brought into the lungs;
- the effective surface area of the alveoli in the lungs;
- the saturation level of the hemoglobin in the red blood cells (RBCs) with oxygen;
- the movement of blood through the circulatory system;
- the dissociation of oxygen from the RBCs; and,
- the association of oxygen with the tissues in the working muscles.

The efficiency of the working muscles to utilize the oxygen transported also affects aerobic fitness. Factors that affect utilization include:

- the intensity of work being performed;
- the sources of energy (carbohydrates and fats) available to the cells in the muscles; and,
- the metabolic pathways used to make the energy required by the muscles.

**Energetics**

The energy requirements of the body are met with a mixture of energy derived from carbohydrates and fats. The intensity of the activity being performed determines the proportion of carbohydrates and fats being utilized and, ultimately, the amount of oxygen needed to utilize those energy sources. 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. At the most intense exercise level, carbohydrates are supplying 100% of the energy 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 because the oxidation of fats requires more oxygen than the oxidation of carbohydrates. The oxidation of a molecule of carbohydrate requires 6 molecules of oxygen and produces 6 molecules of carbon dioxide, a ratio of 1.0, as seen in the following equation:

$$6 \text{O}_2 + \text{C}_6\text{H}_{12}\text{O}_6 = 6 \text{CO}_2 + 6 \text{H}_2\text{O} + 38 \text{ATP}$$
The oxidation of a molecule of fatty acid requires 23 molecules of oxygen and produces 16 molecules of carbon dioxide, a ratio of 0.7, as seen in the following equation:

\[ 23 \text{O}_2 + \text{C}_{16}\text{H}_{32}\text{O}_2 = 16 \text{CO}_2 + 16 \text{H}_2\text{O} + 129 \text{ATP} \]

In turn, the rates at which oxygen and carbon dioxide are exchanged between the alveoli and the capillaries in the lungs are directly proportional to the amounts of oxygen consumed and carbon dioxide produced during cellular respiration in muscles and other organs.

The amounts of oxygen and carbon dioxide exchanged in the lungs 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 air moving into and out of the lungs. When the concentrations and volumes are brought together through a series of equations built into the software of the recording system, the volume of oxygen taken up per minute (\(\text{VO}_2\)) and the volume of carbon dioxide expelled per minute (\(\text{VCO}_2\)) are determined.

The ratio of \(\text{VCO}_2/\text{VO}_2\) is an important parameter known as the Respiratory Exchange Ratio (RER). The RER can be used to determine the proportion of carbohydrates and fats utilized during an activity and the energy expended per liter of oxygen consumed during an activity (Table HE-10-B1). Equations used to determine the percentage of each energy source that is utilized can be found in Appendix I.

**Table HE-10-B1: Respiratory Exchange Ratio (RER) as a Function of the Proportions of Energy Sources.**

<table>
<thead>
<tr>
<th>RER</th>
<th>Energy kcal/liter (\text{O}_2)</th>
<th>% Energy from CHO</th>
<th>% Energy from Fats</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.70</td>
<td>4.69</td>
<td>0</td>
<td>100</td>
</tr>
<tr>
<td>0.75</td>
<td>4.74</td>
<td>15.6</td>
<td>84.4</td>
</tr>
<tr>
<td>0.80</td>
<td>4.80</td>
<td>33.4</td>
<td>66.6</td>
</tr>
<tr>
<td>0.85</td>
<td>4.86</td>
<td>50.7</td>
<td>49.3</td>
</tr>
<tr>
<td>0.90</td>
<td>4.92</td>
<td>67.5</td>
<td>32.5</td>
</tr>
<tr>
<td>0.95</td>
<td>4.99</td>
<td>84.0</td>
<td>16.0</td>
</tr>
<tr>
<td>1.00</td>
<td>5.05</td>
<td>100</td>
<td>0</td>
</tr>
</tbody>
</table>

**Maximal Oxygen Uptake (\(\text{VO}_2\) max) Test**

The best technique for measuring the aerobic fitness of athletes, especially those involved in endurance sports, is the maximal oxygen uptake (\(\text{VO}_2\) max) test.
Warning: The VO2 max test requires the subject to have a reasonable level of fitness. This test is not recommended for recreational athletes or persons with health problems, injuries, or low fitness levels.

In this test, the athlete performs an exercise routine, known as a protocol, using an ergometer on which the workload can be modified. The ergometer should be appropriate for the sport or activity in which the subject participates. The ergometers that are commonly used include treadmills, stationary cycles, rowing machines, and swim benches. The workloads that are programmed into the ergometer progress from moderate to maximal levels in prescribed increments of time and intensity. A variety of protocols suitable for subjects with different levels of aerobic fitness are available. Some are presented in this manual.

In a VO₂ max test, oxygen uptake rate (VO₂) and carbon dioxide production rate (VCO₂) increase as the intensity of exercise being performed by the subject increases. Eventually, the rate of oxygen uptake reaches a plateau. When a plateau in VO₂ values is reached, the VO₂ max test and exercise protocol should be terminated and the recovery period should begin. If the subject’s heart rate is monitored during the recovery period, the time that it takes the subject’s heart rate to return to normal can be used to validate the fitness level of the subject by using one of the tables or nomograms that relate the fitness level to heart rate recovery.

During the exercise protocol, the oxygen and carbon dioxide concentrations in the expired air from the subject are measured using gas analyzers. Concurrently, the lung ventilation volumes of the subject are recorded using a spirometer. The subject’s heart rates at each intensity of exercise and at completion are also measured using a heart rate monitor. Reaching the subject’s maximal heart rate is also an indicator that the VO₂ max test should be terminated. And, if the ergometer has an analog output, the workload put on the subject during different phases of the test can also be recorded.

From the concentrations of oxygen and carbon dioxide in the expired air and the corresponding ventilation volumes recorded during the test, the rates of oxygen uptake (VO₂) and carbon dioxide production (VCO₂) during and at the completion of the test can be calculated using computed functions built into the recording software.

When the VCO₂ in an exercise interval is divided by the corresponding VO₂ from that interval, the quotient is the respiratory exchange ratio (RER). RER can be used as a measure of the energy expended and the proportions of the energy sources (carbohydrates and fats) being consumed during the test. RER values can also be used to determine the point at which the VO₂ max test should be terminated. The VO₂ max test should be terminated when the RER reaches a value of 1.15 or greater.

The VO₂ max test should also be terminated when the subject reaches his or her maximal heart rate. The test can also be terminated when the subject quits the test on his or her own volition because exhaustion has been reached.

Whenever the test is terminated, continue to record the subject’s lung volumes, VO₂, VCO₂, RER, and heart rate to document the subject’s recovery and to validate the fitness level of the subject.

The rates of oxygen uptake (VO₂, VO₂ max) and carbon dioxide expelled (VCO₂) are expressed as minute volumes, with units that are liters per minute (L/min) or milliliters per kilogram of body weight.
per minute (ml/kg/min). The norms for VO$_2$ max for men and women are listed in Table HE-10-B2 and Table HE-10-B3, respectively.

**Table HE-10-B2: Maximal Oxygen Uptake Norms for Men - VO$_2$ max in ml/kg/min**

<table>
<thead>
<tr>
<th>Age (Years)</th>
<th>Fitness Level</th>
<th>18-25</th>
<th>26-35</th>
<th>36-45</th>
<th>46-55</th>
<th>56-65</th>
<th>&gt;65</th>
</tr>
</thead>
<tbody>
<tr>
<td>Excellent</td>
<td>&gt;60</td>
<td>&gt;56</td>
<td>&gt;51</td>
<td>&gt;45</td>
<td>&gt;41</td>
<td>&gt;37</td>
<td></td>
</tr>
<tr>
<td>Good</td>
<td>52-60</td>
<td>49-56</td>
<td>43-51</td>
<td>39-45</td>
<td>36-41</td>
<td>33-37</td>
<td></td>
</tr>
<tr>
<td>Above Average</td>
<td>47-51</td>
<td>43-48</td>
<td>39-42</td>
<td>35-38</td>
<td>32-35</td>
<td>29-32</td>
<td></td>
</tr>
<tr>
<td>Average</td>
<td>42-46</td>
<td>40-42</td>
<td>35-38</td>
<td>32-35</td>
<td>30-31</td>
<td>26-28</td>
<td></td>
</tr>
<tr>
<td>Below Average</td>
<td>37-41</td>
<td>35-39</td>
<td>31-34</td>
<td>29-31</td>
<td>26-29</td>
<td>22-25</td>
<td></td>
</tr>
<tr>
<td>Poor</td>
<td>30-36</td>
<td>30-34</td>
<td>26-30</td>
<td>25-28</td>
<td>22-25</td>
<td>20-21</td>
<td></td>
</tr>
<tr>
<td>Very Poor</td>
<td>&lt;30</td>
<td>&lt;30</td>
<td>&lt;26</td>
<td>&lt;25</td>
<td>&lt;22</td>
<td>&lt;20</td>
<td></td>
</tr>
</tbody>
</table>

**Table HE-10-B3: Maximal Oxygen Uptake Norms for Women - VO$_2$ max in ml/kg/min**

<table>
<thead>
<tr>
<th>Age (Years)</th>
<th>Fitness Level</th>
<th>18-25</th>
<th>26-35</th>
<th>36-45</th>
<th>46-55</th>
<th>56-65</th>
<th>&gt;65</th>
</tr>
</thead>
<tbody>
<tr>
<td>Excellent</td>
<td>&gt;56</td>
<td>&gt;52</td>
<td>&gt;45</td>
<td>&gt;40</td>
<td>&gt;37</td>
<td>&gt;32</td>
<td></td>
</tr>
<tr>
<td>Good</td>
<td>47-56</td>
<td>45-52</td>
<td>38-45</td>
<td>34-40</td>
<td>32-37</td>
<td>28-32</td>
<td></td>
</tr>
<tr>
<td>Above Average</td>
<td>42-46</td>
<td>39-44</td>
<td>34-37</td>
<td>31-33</td>
<td>28-31</td>
<td>25-27</td>
<td></td>
</tr>
<tr>
<td>Average</td>
<td>38-41</td>
<td>35-38</td>
<td>31-33</td>
<td>28-30</td>
<td>25-27</td>
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<tr>
<td>Poor</td>
<td>28-32</td>
<td>26-30</td>
<td>22-26</td>
<td>20-24</td>
<td>18-21</td>
<td>17-18</td>
<td></td>
</tr>
<tr>
<td>Very Poor</td>
<td>&lt;28</td>
<td>&lt;26</td>
<td>&lt;22</td>
<td>&lt;20</td>
<td>&lt;18</td>
<td>&lt;17</td>
<td></td>
</tr>
</tbody>
</table>
HE-10: Aerobic Fitness Testing

Equipment Required

- PC or Mac Computer
- IXTA data acquisition unit and power supply
- USB cable
- Flowhead tubing
  - A-FH-1000 Flow head
  - A-GAK-201 Reusable mask and non-rebreathing valve
- 6ft Smooth interior tubing (35mm I.D.)
- 5 Liter Mixing Chamber
- Nafion gas sample tubing
- GA-200 CO₂/O₂ gas analyzer with filter
- A-CAL-150 Calibration Kit
- PRHMP-220 Heart rate monitor
- Stopwatch
- Treadmill with adjustable speed and gradient
- 3 Liter Calibration syringe

Setup the IXTA

1. Place the IXTA on the bench, close to the computer.
2. Check Figure T-1-1 in Chapter 1 for the location of the USB port and the power socket on the IXTA.
3. Check Figure T-1-2 in Chapter 1 for a picture of the IXTA power supply.
4. Use the USB cable to connect the computer to the USB port on the rear panel of the IXTA.
5. Plug the power supply for the IXTA into the electrical outlet. Insert the plug on the end of the power supply cable into the labeled socket on the rear of the IXTA. Use the power switch to turn on the unit. Confirm that the red power light is on.

Start the Software

1. Click on the LabScribe2 shortcut on the computer’s desktop to open the program. If a shortcut is not available, click on the Windows Start menu, move the cursor to All Programs and then to the listing for iWorx. Select LabScribe from the iWorx submenu. The LabScribe Main window will appear as the program is opens.
2. On the Main window, pull down the Settings menu and select Load Group.

3. Locate the folder that contains the settings group, IPLMv4Complete.iwxgrp. Select this group and click Open.


5. After a short time, LabScribe will appear on the computer screen as configured by the AerobicFitness-LS2 settings.

6. For your information, the settings used to configure the LabScribe software and IXTA units for this experiment are programmed on the Preferences Dialog window, which can be viewed by selecting Preferences from the Edit menu on the LabScribe Main window.

7. 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 flowhead and tubing in the iWorx kit ([Figure HE-10-S1](#)).

![Figure HE-10-S1: The A-FH-1000 flowhead, and airflow tubing.](image)

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-10-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-10-S2).

![Figure HE-10-S2: The mixing chamber.](image)

4. Connect the inlet of the A-FH-1000 flow head to the outlet of the mixing chamber (Figure HE-10-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-10-S3: The 1000L/min flowhead connected to the outlet of the mixing chamber.](image)

5. Locate the non-rebreathing valve, mask, and smooth interior tubing in the iWorx kit (Figure HE-10-S5).

6. Attach one end of the smooth interior tubing to the inlet of the mixing chamber (Figure HE-10-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-10-S4: The PRHMP-220 receiver and GA-200 gas analyzer connected to an IXTA. The flow head will attach to the mixing chamber

Figure HE-10-S5: Mask, non-rebreathing valve, and smooth interior tubing.

8. Locate GA-200A or GA-200B gas analyzer, the gas analyzer power supply, two sensor output cables, a gas inlet filter, and a 6ft long Nafion sampling tubing in the iWorx kit (Figure HE-10-S7).

9. Position the gas analyzer on the desktop, so that the analyzer can be connected to the data recording unit and the mixing chamber at the same time.

10. Place the filter on the inlet port in the lower right front corner of the gas analyzer. Attach the braided end of the Nafion sampling tube to the filter.

11. Place the other end of the Nafion sampling tube on the gas sampling port near the outlet of the mixing chamber (Figure HE-10-S6).
Figure HE-10-S6: The assembled devices used during metabolic studies. The assembly includes: the mixing chamber, smooth interior tubing, Nafion sampling tubing, flowhead, spirometer, non-rebreathing valve, and mask.

Figure HE-10-S7: The GA-200 gas analyzer, inlet filter, and Nafion sampling tubing.

12. Locate the PRHMP-220 Polar™ heart rate monitor transmitter, electrode belt, and receiver in the iWorx kit (Figure HE-10-S8).

13. Plug the phono connector of the PRHMP-220 receiver into the EM1 input on the back of the IXTA.

14. Connect the outputs of the oxygen and carbon dioxide sensors, which are located on the rear panel of the gas analyzer, to the BNC inputs of the recorder.

Human Exercise – AerobicFitness-GA200 – Background

HE-10-9
If the GA-200A is being used in this experiment:

- Connect the specialized cable between the output of the carbon dioxide sensor, which is located on the terminal block on the rear panel of the GA-200A gas analyzer, and the BNC input of Channel A3 on the IXTA:
- Find the color-coded wires on one end of the cable.
- Insert the red wire into Socket 15 on the terminal block, as counted from left to right. This socket is the current output signal of the sensor (Figure HE-10-S9).
- Insert the black wire into Socket 13 on the terminal block, as counted from left to right. This socket is the reference ground for that signal.
- Connect the other end of this cable to the BNC input of Channel A3 on the IXTA.
- Connect the BNC output of the oxygen sensor, labeled Oxygen Sensor and 0-1V=0-100% (9 on page), to BNC input of Channel A4 on the IXTA using a male BNC-BNC cable.

If the GA-200B is being used in this experiment:

- Connect the BNC output of the carbon dioxide sensor, labeled CO2 SENSOR, 0.8-4V=0-10%, to BNC input of Channel A3 on the IXTA using a male BNC-BNC cable.
• Connect the BNC output of the oxygen sensor, labeled Oxygen Sensor and 0-1V=0-100%, to BNC input of Channel A4 on the IXTA using a male BNC-BNC cable.

Figure HE-10-S10: The rear panel of the GA-200B gas analyzer showing the outputs of the carbon dioxide sensor, on the left, and the oxygen sensor, on the right.

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

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 mouth piece and the valve or around the mouthpiece.

If the subject is using a mask:
• 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.

17. Instruct the subject to remove the assembly, but keep the components connected.

18. Insert the coaxial connector on the end of the power supply cable into the socket on the rear panel of the unit that is labeled 12V and 1.5A. Connect the power cord to the power supply. Plug the power cord into the electrical outlet.

19. Use the power switch to turn on the gas analyzer. As the unit powers up, the display on the front of the unit will light up. The gas analyzer must warm up for 30 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.*

1. Load the lab settings file you wish to perform as stated in the “Start the Software” section.
2. Assemble the spirometer, flow head, tubing, mixing chamber and calibration syringe as shown in Appendix I or in the Spirometer Calibration directions.
3. Pull the plunger on the 3L Calibration Syringe all the way out until it stops (Figure HE-10-S20).
4. Click the Record button.
5. Wait for at least 10 seconds of recording so that there is no flow of air moving through the syringe.
6. Push the plunger in all the way until it stops. Pull the plunger out all the way until it stops.
7. Repeat the procedure in Step 6, for 5-10 repetitions, varying the speed and force on the plunger. No wait time is needed between strokes.
8. Wait 5 seconds after the final stroke, then click Stop.
9. On the Expired Air Volume channel, click on STPD Vol.MC (Expired Air Flow). Click SetUp Function to open the Spirometer Calibration dialog box (Figure HE-10-S11).

![Figure HE-10-S11: Spirometer Calibration dialog window.](image-url)
10. Enter these values:
   - Type of flow head - Calibrated
   - Click Load - a new window will open so the *.iwxfcd file that was previously generated can be loaded into your settings. Choose the file and click Open. The name of the *.iwxfcd file that was loaded will appear next to the word “Load”.
   - Atmospheric Pressure – Use the built in baromter or enter the local pressure.
   - Temperature of Mixing Chamber (typically 25 deg C)
   - Baseline use first 10 seconds as zero.
   - Calibrate difference between cursors to 3 Liters

11. Move the left hand cursor to the flat line at the beginning of the calibration recording.
12. Move the right hand cursor to the flat line at the end of the calibration recording.
13. Click Calibrate difference between cursors to so that the calibration curve for this experiment is generated.
14. Click OK.
15. 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.

Calibrating the GA-200 Gas Analyzer

Calibrate the O$_2$ and CO$_2$ Channels

*Note: Warm up the GA-200 for at least 30 minutes prior to use.*

The outputs of the oxygen and carbon dioxide sensors of the GA-200 are voltages that are proportional to the concentrations of the gases being measured by the analyzer. To determine the volumes of oxygen consumed and carbon dioxide produced during metabolic testing, the voltage outputs of the sensors need to be converted, by the recording software, to the percentages of these gases in the inhaled and exhaled air.

To make this conversion, samples of two different concentrations of oxygen, and two different concentrations of carbon dioxide, will need to be put into the GA-300 gas analyzer as the voltage outputs of each sensor are recorded.

One set of samples can be taken from room air, which contains 20.93% O$_2$ and 0.04% CO$_2$. The other set of samples can be taken from gas cylinders containing a combination of these two gases at different concentrations. Cylinders containing both oxygen and carbon dioxide are readily available from suppliers. Some of the most commonly used combinations contain:

- 12% O$_2$ and 5% CO$_2$, with the balance being N$_2$, or;
- 16% O$_2$ and 4% CO$_2$, with the balance being N$_2$.
**Record the Voltage Outputs of the Gas Sensors**

1. Reminder - turn on the GA-200 for at least 30 minutes before performing a calibration.
2. Prepare the equipment that will deliver any gas samples, other than room air, to the GA-200:
   - Clamp and secure any gas cylinders that will be used to provide gas samples near the GA-200 gas analyzer.
   - Attach the regulator to the gas cylinder safely.
   - Attach a Luer-Lock connector to the outlet of the regulator that will allow the Calibration Kit for the GA-200 to be connected to the regulator of the gas cylinder.
   - Open the primary and secondary valves of the regulator for a few seconds to purge the air from the regulator.
   - Close the secondary valve on the regulator to stop the flow of gas from the regulator. You will only need the cylinder for the second sample of gas.
3. Attach a filter to the inlet port on the front of the GA-200 analyzer. Attach the braided end of the sampling tubing to the inlet of the filter.
4. Measure the voltage outputs of the oxygen and carbon dioxide sensors when measuring a sample of room air.
5. Place the gas sampling tubing away from the users to prevent the sampling of exhaled air. Allow room air to be pumped through the gas analyzer for about 10 seconds before recording the outputs of the sensors.
   - Type Room Air in the Mark box to the right of the Mark button.
   - Click on the Record button. The recording should scroll across the screen.
   - While recording, press the Enter key on the keyboard to mark the recording for the room air gas sample.
   - Record the outputs of the two gas sensors for about ten seconds or until the recording levels out. The recording should be like the first segment of data in Figure HE-10-S14.
   - Continue to record while moving to the next series of steps.
6. Measure the voltage outputs of the oxygen and carbon dioxide sensors for a second sample of a gas mixture containing known concentrations of oxygen and carbon dioxide.
   - Open the secondary valve on the regulator of the cylinder providing the second gas sample. Adjust the flow rate to low.
   - While the gas sample is flowing from the regulator, connect the gas sample tubing of the A-CAL-150 Calibration Kit (Figure HE-10-S12) to the Luer-Lock connector on the output of the regulator.
   - Connect the outlet from the A-CAL-150 Calibration Kit to the inlet filter port on the front of the GA-200. The GA-200 will pull the air in from the calibration kit (Figure HE-10-S13).
   - Type Known Gas in the Mark box.
• While continuing to record with the sample gas flowing into the GA-200, press the Enter key on the keyboard to mark the recording for the known gas sample.

![Calibration Kit A-CAL-150]

*Figure HE-10-S12: Calibration Kit A-CAL-150*

7. Once the recordings of the gas concentrations reach a steady level, record for another ten seconds.

8. This can take up to 30 seconds or so.

9. Click the Stop button.

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.

*Convert the Units on Gas Concentration Channels*

1. Use the Display Time icons to adjust the Display Time of the Main window to show the complete calibration data on the Main window at the same time. The required data can also be selected by:

![A-CAL-150 attached to the front of the GA-200 gas analyzer.](image)

*Figure HE-10-S13: A-CAL-150 attached to the front of the GA-200 gas analyzer.*
2. Click the DoubleCursor icon (Figure HE-10-S15) so that two blue cursors appear on the Main window. Place one cursor on the section of data recorded when gas analyzer was collecting a sample of room air and the second cursor on the section of data recorded when the second sample was collected.

3. Convert the voltages at the positions of the cursors to concentrations using the Advanced Units Conversion dialogue window (Figure HE-10-S16).

Figure HE-10-S14: The voltage outputs of the two sensors in the GA-200 gas analyzer, carbon dioxide on the top and oxygen on the bottom. Other recording windows have been minimized to show detail.

Figure HE-10-S15: The LabScribe2 toolbar.
Figure HE-10-S16: The Advanced Units Conversion dialogue window with the voltages between the cursors set to equal the concentrations used in calibration.

4. To convert the voltages on the Expired CO2 Concentration (%) channel, click on the arrow to the left of the carbon dioxide channel to open the channel menu. Select Units from the channel menu, and select Advanced from the submenu.

5. On the Units Conversion window:
   - Make sure Apply units to the next recorded block and Apply units to all blocks are selected in the menu under the displayed graph on the left side of the window by putting a check mark in the boxes next to each statement.
   - Click on and move the cursors so that they are in position such that:
     - the first 2 cursors are on the area where room air was recorded. Leave a space between the cursors so that you have an average value being calculated while room air was moving into the GA-200 gas analyzer.
     - the second 2 cursors are on the area where the known gas sample was recorded. Leave a space between the cursors so that you have an average value being calculated while the gas sample was moving into the GA-200 gas analyzer.
   - Notice that the voltages from the positions between the cursors are automatically entered into the value equations. Enter the two concentrations of carbon dioxide measured from the two samples in the corresponding boxes on the right side of the conversion equations.
     - Room air concentration of CO2 = 0.04
     - The second gas concentration will be the known one from the gas cylinder. Generally a 5% CO2 concentration is recommended.
   - Enter the name of the units, %, in box below the concentrations.
   - Click the OK button in the lower right corner of the window.
6. Repeat Steps 4 and 5 on the Expired O2 Concentration (%) channel.
   • Room air = 20.9
   • Second gas concentration will be the known one from the gas cylinder. Generally a 12% O₂ concentration is recommended.

7. Click on the Save button.

**Note:** When using this LabScribe calibration protocol, the numbers in the software do not correlate with those on the front panel of the GA-200 gas analyzer.

---

**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 (GA200 or GA300). Choose SpirometerCalibration-LS2 to launch the calibration settings file.
3. Assemble the spirometer, flow head, tubing, mixing chamber and calibration syringe.
4. Plug the SP-304 spirometer into the correct channel for the iWorx recording device.
   - IX/214 - Plug the SP-304 spirometer into channel 4.
   - IXTA – Plug the tubing into the spirometer channel A1.
   - IX/228 - Plug the SP-304 spirometer into channel 6.
   - Connect the flow head to the spirometer using the white or gray 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-10-S17**).
   - Connect the smooth side of the tubing to the other ports.
5. Connect end of the 1000L flow head with the red marked onto white flange of the mixing chamber. Make sure the tubing is in an upright direction (**Figure HE-10-S18**).
Figure HE-10-S17: The 1000L flow head.

Figure HE-10-S18: 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-10-19: 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-10-20.

7. Connect the other end of the smooth bore tubing to the mixing chamber, opposite the flow head (Figure HE-10-21).

![Figure HE-10-S20: 3 liter calibration syringe connected to the smooth bore tubing.](image1)

![Figure HE-10-S21: The smooth bore tubing connected to the mixing chamber.](image2)

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-10-19).
   - 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. No wait time is needed 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. Choose a destination on the computer in which to save the file, such as your desktop or other location. Designate the file type as *.iwxdata.
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-10-22).
21. Click the Double Cursor icon so that two blue cursors appear on the Main window.

![Figure HE-10-22: The LabScribe2 toolbar.](image)

22. Click Advanced on the main toolbar. Then click Metabolic, and Calibrate FlowHead (Figure HE-10-23).
23. Place the two blue 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-10-24).
24. In the new window that opens (Figure HE-10-25), enter these values:

- Flow channel = Expired Air Flow
- Baseline = Use the first 10 seconds as zero
- Calibrate difference between cursors to 3 L

Figure HE-10-23: Calibrate FlowHead dialog window.

Figure HE-10-24: The calibration recording showing the blue vertical cursors in the correct position for generating a calibration curve.
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.
HE-10: Aerobic Fitness Testing

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.
Select the Exercise Protocol

Some of the common exercise protocols used to test aerobic fitness are described over the next few pages.

Bruce Treadmill Exercise Protocol

This protocol was developed in the 1950’s by Dr. Robert A. Bruce as a clinical test to evaluate the cardiovascular fitness of patients with suspected coronary heart disease. Currently, it is the most commonly used exercise stress test conducted on a treadmill.

Warning: This test is a maximal test, which requires a reasonable level of fitness. If this test is going to be performed by a recreational athlete or person with health problems, injuries or low fitness levels, please have medical assistance on hand.

1. The test begins with the subject walking on a treadmill at a speed of 2.74 km/hr (1.7 mph) and a gradient of 10% for three minutes (Table HE-10-L1). The stopwatch is started at the beginning of the test to measure the time until the subject is exhausted.

2. After the first stage, the gradient is increased by 2% and the speed is increased to the speed listed for each stage in the table at three minute intervals.

Table HE-10-L1: Speeds and Gradients Used in Each Stage of the Bruce Protocol.

<table>
<thead>
<tr>
<th>Stage</th>
<th>Speed</th>
<th>Gradient</th>
<th>Elapsed Time</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>km/hr</td>
<td>mph</td>
<td>%</td>
</tr>
<tr>
<td>1</td>
<td>2.74</td>
<td>1.7</td>
<td>10</td>
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<td>2</td>
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<td>2.5</td>
<td>12</td>
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<td>3</td>
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<td>7</td>
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<tr>
<td>10</td>
<td>12.07</td>
<td>7.5</td>
<td>28</td>
</tr>
</tbody>
</table>
3. The test proceeds until the subject reaches volitional exhaustion, maximum heart rate, a VO$_2$ plateau, or an RER of 1.15 or greater. The stopwatch is stopped when the subject can no longer continue.

4. Since heart rate is monitored during this test, the determination of the maximum heart rate can be used to set the intensity of exercise in the subject’s training program.

**Astrand Treadmill Protocol**

This protocol is another test that is suitable for athletes involved in endurance sports.

*Warning: This test is a maximal test, which requires a reasonable level of fitness. If this test is going to be performed by a recreational athlete or person with health problems, injuries or low fitness levels, please have medical assistance on hand.*

1. The test begins with the subject jogging on a treadmill at a speed of 8.05 km/hr (5.0 mph) and a gradient of 0% for three minutes (Table HE-10-L2). The stopwatch is started at the beginning of the test to measure the time until the subject is exhausted.

2. In each successive stage, the gradient is increased by 2.5% in two minute intervals while the speed is kept the same.

3. The test proceeds until the subject reaches volitional exhaustion, maximum heart rate, a VO$_2$ plateau, or an RER of 1.15 or greater. The stopwatch is stopped when the subject can no longer continue.

4. Since heart rate is monitored during this test, the determination of the maximum heart rate can be used to set the intensity of exercise in the subject’s training program.
Table HE-10-L2: Speeds and Gradients Used in Each Stage of the Astrand Treadmill Protocol.

<table>
<thead>
<tr>
<th>Stage</th>
<th>Speed</th>
<th>Gradient</th>
<th>Elapsed Time</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>km/hr</td>
<td>mph</td>
<td>%</td>
</tr>
<tr>
<td>1</td>
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<tr>
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<td>8.05</td>
<td>5.0</td>
<td>22.5</td>
</tr>
</tbody>
</table>

**Modified Bruce Treadmill Exercise Protocol**

The Modified Bruce Protocol is used when testing the cardiovascular fitness of elderly or sedentary patients. The modified test starts at a lower workload than the standard test. The first two stages of the Modified Bruce Protocol are performed at 1.7 mph and 0% grade and 1.7 mph and 5% grade. The third stage of the modified protocol corresponds to the first stage of the standard Bruce Protocol.

**Warning:** *This test is a maximal test, which requires a reasonable level of fitness. If this test is going to be performed by recreational athletes or person with health problems, injuries or low fitness levels, please have medical assistance on hand.*

1. The test begins with the subject walking on a treadmill at a speed of 2.74 km/hr (1.7 mph) and a gradient of 0% for three minutes (Table HE-10-L3). The stopwatch is started at the beginning of the test to measure the time until the subject is exhausted.

2. In the second stage of the protocol, the gradient is increased to 5% while the speed is maintained at 2.74 km/hr (1.7 mph) for three minutes.

3. In the third stage of the protocol, the gradient is increased to 10% while the speed is maintained at 2.74 km/hr (1.7 mph) for three minutes.
Table HE-10-L3: Speeds, Gradients, and Times used in each stage of the Modified Bruce and Cornell Treadmill Protocols.

<table>
<thead>
<tr>
<th>Stage</th>
<th>Exercise Intensity</th>
<th>Elapsed Time</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Speed</td>
<td>Gradient</td>
</tr>
<tr>
<td></td>
<td>km/hr</td>
<td>mph</td>
</tr>
<tr>
<td>P1</td>
<td>2.74</td>
<td>1.7</td>
</tr>
<tr>
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<td>2.5</td>
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</tr>
<tr>
<td>5</td>
<td>8.05</td>
<td>5.0</td>
</tr>
</tbody>
</table>

4. After the third stage, the gradient is increased by 2% and the speed is increased to the speed listed for each stage in the table at three minute intervals.

5. The test proceeds until the subject reaches volitional exhaustion, maximum heart rate, a VO$_2$ plateau, or an RER of 1.15 or greater. The stopwatch is stopped when the subject can no longer continue.

6. Since heart rate is also monitored during this test, the determination of the maximum heart rate can be used to set the intensity of exercise in the subject’s training program.

**Cornell Protocol**

The Cornell Protocol has workloads that are gently graded from stage to stage making this test suitable for subjects that might experience heart failure. This protocol contains stages that are whole and half increments of the Bruce Protocol. The stages in the Cornell Protocol are completed in two minute increments, not three minute increments. For a comparison of the Cornell Protocol to the Modified Bruce Protocol, go to Table HE-10-L3.
Warning: This test is a maximal test, which requires a reasonable level of fitness. If this test is going to be performed by recreational athletes or person with health problems, injuries or low fitness levels, please have medical assistance on hand.

1. The test begins with the subject walking on a treadmill at a speed of 2.74 km/hr (1.7 mph) and a gradient of 0% for two minutes (Table HE-10-L3). The stopwatch is started when the test is started to measure the total amount of time that passes until the subject is exhausted.

2. In the next increment of the protocol, the gradient is increased to 5% while the speed is maintained at 2.74 km/hr (1.7 mph) for two minutes.

3. In the successive increments of the protocol, the gradient is increased by 10% while the speed is maintained at 2.74 km/hr (1.7 mph) for two minutes.

4. After the third increment, the gradient is increased by 2% per increment and the speed is increased to the speed listed for each increment.

5. The test proceeds until the subject reaches volitional exhaustion, maximum heart rate, a VO\textsubscript{2} plateau, or an RER of 1.15 or greater. The stopwatch is stopped when the subject can no longer continue.

6. Since heart rate is also monitored during this test, the determination of the maximum heart rate can be used to set the intensity of exercise in the subject’s training program.

Naughton Protocol

The Naughton Protocol is a low intensity exercise protocol that has incremental increases in workload that are more gradual than the Bruce Protocol. Because of these gradual increases, the cardiovascular response of a subject to the workload has a greater linearity than other protocols. The protocol is frequently used on subjects that are debilitated by heart failure.

1. The test begins with the subject walking on a treadmill at a speed of 1.93 km/hr (1.2 mph) and a gradient of 0% for two minutes (Table HE-10-L4). The stopwatch is started when the test is started to measure the total amount of time that passes until the subject is exhausted.

2. In the second stage, the speed is increased to 2.41 km/hr (1.5 mph) while the gradient is maintained at 0%.

3. In each of the next three stages, the speed is maintained at 2.41 km/hr (1.5 mph) while the gradient is increased by 3% every two minutes.

4. In the sixth stage, the speed is increased to 3.21 km/hr (2.0 mph) while the gradient is increased to 12%.

5. The test proceeds until the subject reaches volitional exhaustion, maximum heart rate, a VO\textsubscript{2} plateau, or an RER of 1.15 or greater. The stopwatch is stopped when the subject can no longer continue.

6. Since heart rate is monitored during this test, the determination of the maximum heart rate can be used to set the intensity of exercise in the subject’s training program.
Table HE-10-L4: Speeds, Gradients, and Times used in each stage of the Naughton Protocol.

<table>
<thead>
<tr>
<th>Stage</th>
<th>Speed km/hr</th>
<th>Gradient</th>
<th>Elapsed Time</th>
<th>Minutes</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
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<td>6</td>
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</tr>
<tr>
<td>6</td>
<td>3.21</td>
<td>2.0</td>
<td>12</td>
<td>12</td>
</tr>
</tbody>
</table>

**Balke Treadmill Protocol**

The Balke Treadmill Protocol is another assessment of aerobic fitness that is recommended for cardiac patients since the increase in workload is moderate. The protocol is considered safe for patients with severe left ventricular dysfunction.

1. The test begins with the subject walking on a treadmill at a constant walking and a gradient of 0%. A stopwatch is started at this time to measure the total amount of time that passes until the subject is exhausted.

2. Depending on the gender of the subject, the gradient is increased every one minute, two, or three minutes.

3. The test proceeds until the subject reaches volitional exhaustion, maximum heart rate, a VO$_2$ plateau, or an RER of 1.15 or greater. The stopwatch is stopped when the subject can no longer continue.

4. Since heart rate is monitored during this test, the determination of the maximum heart rate can be used to set the intensity of exercise in the subject’s training program.

5. There are several variations of the Balke Treadmill Protocol. Here are some examples of these variations that have been used.

   - For active and sedentary men, the treadmill speed is set at 5.28 km/hr (3.3 mph) with a gradient of 0%. After 1 minute, the gradient is raised to 2%. At each successive one minute interval, the gradient is increased by 1%.

   - For active and sedentary women, the treadmill speed is set at 4.81 km/hr (3.0 mph) with a gradient of 0%. After three minutes, the gradient is increased by 2.5% at each three minute interval.

   - For all subjects, the treadmill speed is set at a constant speed of 3.00 km/hr (1.88 mph) as the gradient is increased by 2.5% at each two minute interval.
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-10-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-10-L1: Online Metabolic Calculations dialog window.*

**Conduct the VO₂ max Test**

1. While preparations are being completed, have the subject become accustomed to wearing the non-rebreathing valve with either a mouthpiece or a mask. The subject must be able to breathe normally before any recordings can be made.
2. Remind the subject and all the persons assisting in the test about the specifications of the exercise protocol being used.

3. Wet the cloth electrode patches on the inside of the PHRM-100 belt with water. Position the belt around the chest of the subject with the electrodes making contact with the skin that is over the heart. Snap the heart rate transmitter to the electrode belt so that the label is right side up. The subject can wear a shirt since it will not interfere with the operation of the PHRM-100.

4. Once the subject and recording equipment is all prepared, have the subject remove the mask from his or her mouth and hold the non-rebreathing valve and mask in a position so that the subject’s breath is not moving through the valve.

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

5. Type <Subject’s Name> baseline in the Mark box that is to the right of the Mark button.

6. Click on the Record button. After waiting ten seconds for the Lung Volume channel to zero, the subject should put the mask over his or her face and adjust the positioning to create a tight seal. The assembly should be firmly, but comfortably, attached to head of the subject.

7. Press the Enter key on the keyboard to mark the recording as the subject begins breathing through the mask and the flowhead.

8. The subject should record a baseline reading for at least 5 to 10 minutes to exchange the air in the mixing chamber. Once the mixing chamber air has been replaced by the subject’s expired air, the test protocol can begin.

   - The trace on the CO₂ Concentration (%) channel increases as the mixing chamber fills with exhaled air. It gradually increases as the fitness test proceeds.
   - The trace on the O₂ Concentration (%) channel decreases as the mixing chamber fills with exhaled air. It gradually decreases as the fitness test proceed

9. Type <Subject’s Name> Stage 1 in the Mark box that is to the right of the Mark button.

10. Press the Enter key on the keyboard to mark the recording as the subject begins breathing through the mask and the flowhead. Start the stopwatch to keep track of the time in each stage of the exercise protocol.

11. Click the AutoScale buttons on all channels and make sure all channels are being recorded properly (**Figure HE-10-L2**).

   - The trace on the Heart Rate Monitor channel registers a spike for each heart beat.
   - The trace on the Air Flow channel records an individual peak for each breath exhaled by the subject
   - The trace on the Lung Volume STPD channel increases steadily as the cumulative volume of air exhaled by the subject is recorded.
   - The trace on the Heart Rate channel should appear as a histogram that traces the heart
rate between beats.

12. Follow the exercise protocol selected and change the speed and/or elevation of the treadmill at the times listed in the protocol. Enter the name of each stage in the Mark box and press the Enter key to mark the recording at the beginning of each stage of the protocol.

13. Continue to record as the subject exercises. Observe the changes in the O2 and CO2 concentrations, the air flow per breath and the total volume of air exhaled from the lungs as the protocol continues.

14. Click the Stop button to halt the exercise protocol when the subject reaches volitional exhaustion, or his or her maximum heart rate.

15. 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.

![Graph](image.png)

Figure HE-10-L2: The CO₂ Concentration (%), O₂ Concentration (%), Air Flow, and Lung Volume STPD channels shown on the Main window.
Calculate and Plot Metabolic Parameters

Values for VO$_2$, VCO$_2$, RER, TV, and other parameters (Table HE-10-L5) 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 CO$_2$, O$_2$, 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-10-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-10-L6) 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.

Interpret the Data

1. Compare the VO$_2$ value from the last minute of the last exercise segment completed by the subject to the values for the subject’s age group in Table HE-10-L7 or Table HE-10-L8.

2. Determine the fitness level of the subject based on the subject’s VO$_2$ level.

3. What is the subject’s RER in the last minute of the last exercise segment completed?

4. In which minute of which segment does the slope of VE/VO$_2$ change significantly? This dramatic increase in slope indicates the anaerobic threshold.

5. If the work performed is also being recorded, at which workload is the ratio of VO2/HR the greatest?
### Table HE-10-L5: List of Parameters Calculated on the Mixing Chamber Offline Metabolic Window

<table>
<thead>
<tr>
<th>Term</th>
<th>Parameter</th>
<th>Description</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>Abs.(\text{VO}_2)</td>
<td>Absolute (\text{VO}_2)</td>
<td>Volume of oxygen (O2) consumed per minute</td>
<td>Liters/minute</td>
</tr>
<tr>
<td>Abs.(\text{VCO}_2)</td>
<td>Absolute (\text{VCO}_2)</td>
<td>Volume of carbon dioxide (CO2) produced per minute</td>
<td>Liters/minute</td>
</tr>
<tr>
<td>Rel.(\text{VO}_2)</td>
<td>Relative (\text{VO}_2)</td>
<td>Volume of O2 consumed per kg body weight per minute</td>
<td>milliliters/kg/minute</td>
</tr>
<tr>
<td>Rel.(\text{VCO}_2)</td>
<td>Relative (\text{VCO}_2)</td>
<td>Volume of CO2 produced per kg body weight per minute</td>
<td>milliliters/kg/minute</td>
</tr>
<tr>
<td>RER</td>
<td>Respiratory Exchange Ratio</td>
<td>Ratio of (\text{VCO}_2/\text{VO}_2)</td>
<td>None</td>
</tr>
<tr>
<td>REE</td>
<td>Resting Energy Expenditure</td>
<td>5.46 (Absolute (\text{VO}_2)) + 1.75 (Absolute (\text{VCO}_2)) kcal/day</td>
<td>kcal/day</td>
</tr>
<tr>
<td>TV</td>
<td>Tidal Volume</td>
<td>Volume of air displaced during a normal breath cycle - inhalation and exhalation</td>
<td>Liters/breath</td>
</tr>
<tr>
<td>RR</td>
<td>Respiratory Rate</td>
<td>Number of breaths per minute; ((60 \text{ sec/min}) / \text{breath period (sec/breath)})</td>
<td>Breaths per minute</td>
</tr>
<tr>
<td>METS</td>
<td>Metabolic Equivalent of Task</td>
<td>(1 \text{ MET} = 3.5\text{ml} \text{O}_2/\text{kg/min} \text{ or } 1\text{kcal/kg/hr})</td>
<td>MET</td>
</tr>
<tr>
<td>(\text{O}_2) Min.</td>
<td>(\text{O}_2) Minimum - exhalation</td>
<td>Minimum concentration of (\text{O}_2) recorded during test period</td>
<td>Percentage</td>
</tr>
<tr>
<td>(\text{CO}_2) Max.</td>
<td>(\text{CO}_2) Maximum - exhalation</td>
<td>Maximum concentration of (\text{CO}_2) recorded during test period</td>
<td>Percentage</td>
</tr>
<tr>
<td>VI</td>
<td>Inspired Tidal Volume</td>
<td>Volume of air displaced during normal inhalation</td>
<td>Liters/breath</td>
</tr>
<tr>
<td>VE</td>
<td>Expired Tidal Volume</td>
<td>Volume of air displaced during normal exhalation</td>
<td>Liters/breath</td>
</tr>
<tr>
<td>(P)</td>
<td>Power</td>
<td>Workload during the stages of the test</td>
<td>Watts</td>
</tr>
<tr>
<td>HR</td>
<td>Heart Rate</td>
<td>Number of beats in a minute calculated by dividing (60 sec/min) by the beat period (sec/breath)</td>
<td>Beats per Minute</td>
</tr>
</tbody>
</table>
Table HE-10-L6: Plots Available on the Offline Metabolic Window.

| Available Plots | |
|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|
| Y-Axis Parameter 1 | VO₂ | VCO₂ | Ve | Vₐ | HR | Ve | HR | VO₂ | Ve/VO₂ | RER |
| Y-Axis Parameter 2 | VCO₂ | | | | | | VCO₂ | VO₂/HR | VCO₂ | |
| Y-Axis Parameter 3 | RER | | | | | | | | | |
| X-Axis Parameter | Time | VO₂ | VO₂ | VCO₂ | VO₂ | Ve | Watts | Watts | Watts | Watts | Watts |

*Human Exercise – AerobicFitness-GA200 – Background*
Figure HE-10-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.