**RQ/RER LAB**

Name___________________________Lab_____

**Introduction:**
Because of the differences in composition of food fuels, different amounts of oxygen are required to completely oxidize those foods to carbon dioxide and water. Thus, the quantity of carbon dioxide produced in relation to oxygen consumed varies depending on the substrate metabolized. This ratio of metabolic gas exchange is termed the respiratory quotient (RQ):

\[
\text{RQ or RER} = \frac{\text{CO}_2 \text{ produced}}{\text{O}_2 \text{ uptake}}
\]

Strictly speaking, RQ is calculated at the cellular level. Since that is not easy to determine we do the same calculation using expired air, and call it RER. The terms are often used interchangeably though their distinction is important to understand. RER provides a convenient guide to the nutrient mixture being catabolized for energy during activity. Also, it allows for a more precise determination of caloric expenditure because caloric equivalent varies slightly with the nutrient being oxidized. For carbohydrate oxidation glucose yields 6 CO₂ for 6 O₂ consumed.

\[
\text{C}_6\text{H}_{12}\text{O}_6 + 6 \text{ O}_2 \rightarrow 6 \text{ CO}_2 + 6 \text{ H}_2\text{O}
\]

\[
\text{RQ or RER} = \frac{6 \text{ CO}_2}{6 \text{ O}_2} = 1.00
\]

The ratio of hydrogen to oxygen in carbohydrates is equal to that of water. All of the oxygen consumed by cells is used to oxidize the carbon in the carbohydrate to carbon dioxide. In turn, the resultant production of carbon dioxide is equal to oxygen consumed and the ratio is 1.00.

Lipids contain considerably fewer oxygen atoms in proportion to atoms of hydrogen and carbon. Thus, when fat is degraded relatively more oxygen is needed to oxidize fat to carbon dioxide and water. In the example of palmitic acid, 23 O₂ molecules are consumed for the oxidation of 16 CO₂ molecules:

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

\[
\text{RQ or RER} = \frac{16 \text{ CO}_2}{23 \text{ O}_2} = 0.696 \text{ or } 0.7
\]

Proteins are not simply oxidized to carbon dioxide and water during energy metabolism. The protein is deaminated and the nitrogen and sulfur are excreted. The resulting keto fragments are then oxidized. These short chain keto fragments require more oxygen for complete combustion in relation to CO₂ produced, similar to lipids. All of this complicates things, but since so little protein is used as fuel we just ignore protein. Thus, we use a non-protein RER assuming that the metabolic mixture is comprised only of carbohydrate and fat.

During activities that range from bed rest to light aerobic exercise the RER seldom reflects the oxidation of pure carbohydrate or pure fat. Instead, a mixture of these nutrients is used, and the RER falls between 0.7 and 1.00. Table 11-4 on page 287 of your text presents the energy expenditure per liter of O₂ uptake for different non-protein RER values. Also presented are the corresponding percentages and grams of carbohydrate and lipid utilized for energy.

RER calculations are based on the assumption that the exchange of oxygen and carbon dioxide measured at the lungs reflects actual gas exchange from nutrient metabolism. At rest and during light exercise this assumption is reasonably valid. Factors that disturb the normal metabolic relationship between these gases may drastically alter the ratio. For example,
hyperventilation increases carbon dioxide elimination because the response of breathing is disproportionately high in relation to the metabolic demands of a particular exercise intensity. In other words, the increase in carbon dioxide elimination is not accompanied by a corresponding increase in oxygen uptake. In such cases the ratio of carbon dioxide produced to oxygen consumed exceeds 1.00. We have seen such hyperventilatory responses during prior labs. Under such conditions we can no longer assume that the RER is an accurate reflection of the fat and carbohydrate mixture. In strenuous or exhaustive exercise the RER may exceed 1.00 due to respiratory responses to counteract rising blood acidity due to both lactic acid and rising CO₂ in the blood.

**EXAMPLE:** During 30 minutes of steady-state exercise a subject averages an oxygen consumption of 3.22 L/min with a CO₂ production of 2.78 L/min.

\[
\text{RQ or RER} = \frac{2.78}{3.22} = 0.86
\]

\[
\text{kcals/liter O}_2 = 4.875
\]

\[
4.875 \text{ kcals/liter x 3.22 L/min} = 15.7 \text{ kcals/min}
\]

So, you can conclude that 54.1% of the calories came from carbohydrates and 45.9% came from lipids. Or 0.621 grams of carbohydrate per liter of oxygen consumed and 0.247 grams of lipid per liter of oxygen consumed.

\[
0.621 \text{ grams CHO/liter O}_2 \times 3.22 \text{ L/min} = 1.999 \text{ grams/min}
\]

\[
0.247 \text{ grams lipid/liter O}_2 \times 3.22 \text{ L/min} = 0.795 \text{ grams/min}
\]

Calculating as 4 kcals per gram CHO, and 9 kcals per gram of lipid:

\[
4 \text{ kcals/gram CHO} \times 1.999 \text{ grams/min} = 7.99 \text{ kcals/min from CHO}
\]

\[
9 \text{ kcals/gram lipid} \times 0.795 \text{ grams/min} = 7.155 \text{ kcals/ min from lipid}
\]

**PRACTICE EXAMPLE:**
While walking on the treadmill a person is consuming 1.4 Liters of oxygen per minute. Her RER is 0.77. What is the energy expenditure per minute and the percentage contributions of carbohydrate and lipids to that energy expenditure?

**Purpose:**
The purpose of this lab is to examine the individual fuel utilization during the separate stages of the Bruce protocol.

**Equipment/Personnel:**
- Metabolic cart, face mask/mouthpiece, headgear, treadmill, blood pressure cuff, sphygmomanometer, RPE scale, one subject, and five assistants.

**Definitions:**
1. **Respiratory Exchange Ratio (RER)** - The ratio of the volume of CO₂ produced divided by the volume of O₂ consumed, calculated using expired air.
2. **Respiratory Quotient (RQ)**- The ratio of the amount of CO₂ produced divided by the amount of O₂ consumed at the cellular level.

3. **Caloric Equivalent**- The number of kilocalories provided per liter of O₂ consumed.

4. **Caloric Cost**- Energy expenditure of an activity, usually expressed “per minute”.

**Procedures:**

The subject will be asked to perform the Bruce protocol on the treadmill. During the test assistants will keep track of assigned metabolic activities and attend to the subject. Respiratory exchange ratio values will be calculated from the information obtained from the metabolic cart.

**TODAY’S TEST:**

<table>
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<th>Minute</th>
<th>Speed</th>
<th>% grade</th>
<th>Liters O₂/min</th>
<th>%O₂</th>
<th>%CO₂</th>
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<td>REST</td>
<td>__________</td>
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<tr>
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<td>2.5 mph</td>
<td>12</td>
<td>__________</td>
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<tr>
<td>____</td>
<td>3.4 mph</td>
<td>14</td>
<td>__________</td>
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<tr>
<td>____</td>
<td>5.0 mph</td>
<td>18</td>
<td>__________</td>
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</table>

**Readings:**

Plowman 131-136

**Questions/Speculations:**

1. Calculate the energy expenditure and the relative contributions of fat and carbohydrates being catabolized for rest and the first three workloads.

2. How many grams of fat and carbohydrates are being utilized at each workload?

3. Based upon the information obtained during lab, “What is the best exercise to burn fat?”