Module II

Properties of Carbohydrates: Considerations for Sports Performance
Carbohydrates and Performance
General Recommendations for Carbohydrate Intake During Exercise
Properties of Carbohydrates:

Considerations for Sports Performance
What Is the Glycemic Index?

- System of ranking foods according to how much they raise blood glucose relative to a reference food
- Rapidly digested or absorbed carbohydrates = high GI
- Slowly digested or absorbed carbohydrates = low GI
- References on GI
    - Written by experts on GI
    - Most comprehensive table of the GI of foods that has been assembled to date

Abbreviations: GI, glycemic index.
Figure from [http://www.glycemicindex.com/aboutGI.htm](http://www.glycemicindex.com/aboutGI.htm).
What Does the Glycemic Index Value Mean?

- The glycemic index (GI) is expressed as a ratio comparing the blood glucose increase caused by a test food to that of a reference food (usually glucose [G], historically white bread [WB]) for 2 hours following ingestion:

  \[
  \frac{\text{Area Under the Curve for Test Food}}{\text{Area Under the Curve for Reference Food}} \times 100 = \text{GI}
  \]

- Conversion for different reference foods: \( \text{GIG} \times 1.4 = \text{GIWB} \)
  - The GIG for carrots (mean of 4 studies) = 47
  - The GIWB for carrots (mean of 4 studies) = 68

What Is the Glycemic Load?

- The glycemic load (GL) takes into account the amount of carbohydrate (CHO) in a common serving in addition to its glycemic index (GI):

  \[
  \text{GL} = \left( \text{GI of CHO} \times \text{grams of CHO per serving} \right) \div 100
  \]

- Example:
  - Carrots (peeled, boiled) have a GI of 47 and 5 g CHO per serving

  The \(\text{GL}_g\) of carrots is: \((47 \times 5) \div 100 = 2.4\)

Abbreviations: CHO, carbohydrate; GL, glycemic load; GI, glycemic index.
Glycemic Index and Load Standards for Foods

- **GI (based on glucose reference)**
  - Low GI 0 to 55
  - Intermediate GI 56 to 69
  - High GI ≥ 70

- **GL (based on glucose reference)**
  - Low GL 0 to 10
  - Intermediate GL 11 to 19
  - High GL ≥ 20

Abbreviations: GI, glycemic index; GL, glycemic load.
Usefulness of Glycemic Index and Glycemic Load

- Diabetes control with low GI foods and diets
  - Supplement to exchange lists
  - Category B evidence according to ADA
  - Positive meta-analysis

- Sports nutrition (pre- and postexercise)\(^1\)
  - Low-GI foods before endurance exercise (shaky evidence)
  - High-GI foods after exercise (strong evidence of benefit)

- Reduced CVD risk with low GI/low GL\(^2\)
  - Mostly epidemiologic evidence

- Weight control with low GI/low GL\(^3\)

- Lowered risk of several types of cancer with low GI/low GL\(^4,5\)
  - Mostly epidemiologic evidence

Abbreviations: ADA; American Diabetes Association; CVD, cardiovascular disease; GI, glycemic index; GL, glycemic load.

Blood Glucose Response to High vs Low Glycemic Index Foods

- Data on blood glucose responses to bread and lentils in a subject without diabetes

![Graph showing blood glucose response to bread and lentils over time.](image)

Blood Glucose Response to Foods With Varying Glycemic Index

Blood Glucose Areas Under the Curve for the 4 Meals (mmol•min/L)

<table>
<thead>
<tr>
<th></th>
<th>Blood Glucose Areas Under the Curve (mmol•min/L)</th>
</tr>
</thead>
<tbody>
<tr>
<td>White bread</td>
<td>166.1 ± 31.7</td>
</tr>
<tr>
<td>Candy bar</td>
<td>161.6 ± 19.4</td>
</tr>
<tr>
<td>Moderate-carbohydrate</td>
<td>91.9 ± 22.6</td>
</tr>
<tr>
<td>High-carbohydrate</td>
<td>125.0 ± 21.6</td>
</tr>
</tbody>
</table>

Slowly and Fully Digested Carbohydrates (Low GI)

- **Isomaltulose**
  - Glucose and fructose linked by an alpha-1,6 bond
  - Results in a more steady and sustained release of glucose into the blood compared with sucrose
  - Occurs naturally in honey, but can be synthesized from sucrose

- **Sucromalt**
  - Produced by enzymatic conversion of sucrose and maltose into a fructose and oligosaccharide syrup
    - Oligosaccharide is made of glucoses linked by alternating alpha-1,3 and alpha-1,6 linkages
  - Digestion profile similar to isomaltulose

- **Gamma-cyclodextrin**
  - Ring of 8 glucose molecules

Abbreviations: CHO, carbohydrate; GI, glycemic index.
Glycemic Response to Slowly Digested Carbohydrates

Letters denote statistical differences.

Glycemic Index and Sports Nutrition

- **Pre-exercise (1 to 2 hours):**
  - Low-GI foods for endurance
  - Alters substrate utilization (↑ free fatty acids, more stable glucose, ↓ insulin)
  - No consistent effects on performance observed, despite above
    - How is performance measured?
      - Time to exhaustion vs time trial
    - Carbohydrate intake during exercise eliminates need for low GI pre-exercise

- **Postexercise:**
  - High-GI foods and high insulin response increase rate of muscle glycogen synthesis

Abbreviation: GI, glycemic index.
Plasma Glucose Response to Energy Gels

(N = 15)

Bores J. “The glycemic index of energy gels in normal volunteers” [honors thesis]. The Ohio State University. 2003.
Key Methodologic Issues for Glycemic Index

- **Time of sampling**
  - 2 hours after start of test meal (non-diabetes)
    - 0, 15, 30, 45, 60, 90, and 120 minutes
  - 3 hours after start of test meal (diabetes)

- **Standardized amount of carbohydrate** (50 g available carbohydrate, usually)

- **Method of blood glucose sampling**
  - Capillary finger stick or arterial blood more sensitive than venous blood

- **Method of calculating area under the curve (AUC)**
  - Positive incremental AUC vs total or net AUC

Other Methodologic Issues for Glycemic Index

- Choice of reference food (glucose vs white bread)
- Number of repetitions with reference and test foods
- How the food GI is calculated
  - Should calculate AUC of test and reference foods and the GI for each individual subject
  - Use the mean of the individual GIs as the GI for the food
  - Do not calculate the GI based on the mean AUCs for test and reference foods

Abbreviations: AUC, area under the curve; GI, glycemic index.
Progress Check—Considerations for Sports Performance

1. Ingestion of low versus high glycemic index foods before or during exercise has clear performance benefits.
   A. True
   B. False

2. Glycemic load is based on which of the following concepts?
   A. Only carbohydrate ingestion determines exercise performance
   B. Only the glycemic response of the overall diet determines exercise performance
   C. Both the amount of carbohydrate per serving and the glycemic index of that carbohydrate influence the blood glucose response
   D. Stored glycogen in muscles determines exercise performance

3. Which statement regarding carbohydrates is NOT true?
   A. Slow and fully digested carbohydrates result in a more steady and sustained release of glucose into the blood compared with sucrose
   B. High-GI carbohydrates increase rates of muscle glycogen synthesis
   C. High-GI foods after exercise show strong evidence for glycogen recovery
   D. Low-GI foods before endurance exercise show strong evidence of exercise benefit
Progress Check—Considerations for Sports Performance

1. Ingestion of low versus high glycemic index foods before or during exercise has clear performance benefits.

✗ A. True

Incorrect, please review slide Glycemic Index and Sports Nutrition to better understand the effects of glycemic index foods on performance during exercise.

✔ B. False

Correct, intake of low versus high glycemic index foods before or during exercise has not shown clear performance benefits.
Progress Check—Considerations for Sports Performance

2. Glycemic load is based on which of the following concepts?

✗ A. Only carbohydrate ingestion determines exercise performance
   Incorrect, please review slide What Is the Glycemic Load? to better understand the calculation and definition of glycemic load.

✗ B. Only the glycemic response of the overall diet determines exercise performance
   Incorrect, please review slide What Is the Glycemic Load? to better understand the calculation and definition of glycemic load.

✓ C. Both the amount of carbohydrate per serving and the glycemic index of that carbohydrate influence the blood glucose response
   Correct, both amount and glycemic index of carbohydrates influence glucose response.

✗ D. Stored glycogen in muscles determines exercise performance
   Incorrect, please review slide What Is the Glycemic Load? to better understand the calculation and definition of glycemic load.
Progress Check—Considerations for Sports Performance

3. Which statement regarding carbohydrates is NOT true?

✗ A. Slow and fully digested carbohydrates result in a more steady and sustained release of glucose into the blood compared with sucrose. Incorrect, please review slide Slowly and Fully Digested Carbohydrates (Low GI) to better understand the benefits from low-GI carbohydrates.

✗ B. High-GI carbohydrates increase rates of muscle glycogen synthesis. Incorrect, please review slide Glycemic Index and Sports Nutrition to better understand the effects of high-GI carbohydrates on the body.

✗ C. High-GI foods after exercise show strong evidence for glycogen recovery. Incorrect, please review slide Usefulness of Glycemic Index and Glycemic Load to better understand the benefits from high-GI foods.

✓ D. Low-GI foods before endurance exercise show strong evidence of exercise benefit. Correct, low-GI foods before endurance exercise do not show strong evidence of benefit in sports.
Carbohydrates and Performance
Carbohydrate and Fat Use at Different Exercise Intensities

- As the intensity of exercise increases, muscle glycogen constitutes a greater portion of the energy source.

Abbreviation: FFA, free fatty acid.
Fuel Substrates Used Over the Course of Exercise

High-Carbohydrate Diet and Time to Exhaustion

- Subjects (n = 9) cycled to exhaustion before diets
- Diets were fed for 3 days:
  - Mixed diet (self selected)
  - Protein and fat diet (2,800 kcal, 46% fat, 54% protein)
  - High-carbohydrate diet (2,800 kcal, 82% carbohydrate, 18% protein)
- Subjects cycled to exhaustion at end of each diet

Effect of High- vs Moderate-Carbohydrate Diet on Muscle Glycogen and Rowing Power

- High CHO diet provided increased muscle glycogen reserves and power output compared with a moderate CHO diet in rowers.

- Diets were either 5 or 10 g CHO per kg body weight for training period duration
  - (55 kg individual: 275 for low, 550 g for high)
  - (75 kg individual: 375 for low, 750 g for high)

- Muscle glycogen (vastus lateralis) and average rowing power output were measured in members of a collegiate rowing team.

Abbreviation: CHO, carbohydrate.
Effect of High- vs Moderate-Carbohydrate Diet on Running Endurance (70% VO_{2max})

- Two runs spaced 22.5 hours apart
- CHO intake of control group (blue):
  - 5.8 g/kg/day during recovery
- CHO intake of high-CHO group (red):
  - 8.8 g/kg/day during recovery

Abbreviation: CHO, carbohydrate; VO_{2max}, maximal oxygen consumption.
Carbohydrate Loading

- **Traditional protocol**
  - Depletion of glycogen stores (~ Days 6 to 3 before event)
    - Low-carbohydrate diet and hard exercise
  - Supercompensation of muscle glycogen (~ Day 3 before event to day of event)
    - Very high-carbohydrate diet (8 to 12 g/kg body weight/day) and tapering of exercise

- **Cons**
  - Depletion phase is hard on the body and difficult to tolerate in training
    - May lead to headaches, irritability, and increased risk of injury
Is the Strict Carbohydrate-Loading Protocol Necessary?

- Depletion phase was not needed to influence glycogen storage (Group A vs B)
- Performance on 20.9-km run was not affected
  - Run was probably too short for muscle glycogen to be the limiting factor

Depletion-tapered training in all groups followed by a 20.9-km run (~13 miles).
Abbreviation: CHO, carbohydrate.
Carbohydrate Ingestion During Exercise

- Having high glycogen stores is very important to prolonging endurance
  - Related to diet and exercise in the days and hours before event
  - Endogenous carbohydrate oxidation at high intensity
  - Especially important for events longer than 90 to 120 minutes (eg, marathons and cycling events)

- What is the role of exogenous (ingested) carbohydrate oxidation?
  - Can exogenous carbohydrate spare glycogen stores (liver and or muscle)?
  - Can dietary carbohydrate have other effects (central nervous system)?
Evidence for Efficacy of Carbohydrates Consumed During Exercise

- Jeukendrup (2004) reviewed multiple studies (n = 22) of walking, running, and cycling in which carbohydrates were given during exercise
  - 23 of 36 observations within these studies showed a positive effect of carbohydrate on endurance
  - Effective dose
    - Minimum, 16 to 22 g carbohydrate/hour
    - Maximum, 75 g carbohydrate/hour
  - No studies showed an adverse, or ergolytic, effect of carbohydrate on performance
  - Form of carbohydrate (solid or liquid) was of little significance, although the vast majority of the studies used a beverage

Use of Multiple Transportable Carbohydrates

- Oxidation of any single type of carbohydrate during exercise is limited to 1 g/min or less

- Limiting factor is the ability of the intestine to absorb the carbohydrate
  - Saturation of intestinal sugar transporters is key

- Giving carbohydrates that are absorbed by different intestinal sugar transporters can
  - Help to bypass, to some degree, the limited intestinal absorption of carbohydrate
  - Increase exogenous carbohydrate oxidation during exercise to 1.2-1.5 g/min

- Probably only important in long-duration and very-intense physical efforts such as full triathlons (e.g., Ironman) or cycling races such as the Tour de France

Effects of Multiple Transportable Carbohydrates on Exogenous Carbohydrate Oxidation

Carbohydrate Ingestion Rate, g/min vs. Exogenous Carbohydrate Oxidation, g/min

- 100% exogenous carbohydrate oxidation
- Average observed rate
- Carbohydrates using different transporters
- Single carbohydrates

Progress Check—Carbohydrates and Performance

1. Carbohydrate consumption during extended (greater than 45 minutes) exercise usually improves performance.
   A. True
   B. False

2. Which of the following carbohydrate intakes would be most appropriate for an endurance athlete (e.g., marathoner) who is carbohydrate loading two days before an event?
   A. 1 g per pound body weight per day
   B. 8-12 g/kg body weight per day
   C. 1500 g/day
   D. All of the above intakes are too low

3. Maximal glycogen stores are important for endurance.
   A. True
   B. False
Progress Check—Carbohydrates and Performance

1. Carbohydrate consumption during extended (greater than 45 minutes) exercise usually improves performance.

✓ A. True

Correct, carbohydrate consumption during long exercise periods can improve performance.

✗ B. False

Incorrect, please review slide Evidence for Efficacy of Carbohydrates Consumed During Exercise to better understand the effects of carbohydrate consumption on performance during exercise.
Progress Check—Carbohydrates and Performance

2. Which of the following carbohydrate intakes would be most appropriate for an endurance athlete (e.g., marathoner) who is carbohydrate loading two days before an event?

✗ A. 1 g per pound body weight per day
   *Incorrect, please review slide Carbohydrate Loading to better understand the carbohydrate loading protocol.*

✓ B. 8-12 g/kg body weight per day
   *Correct, this amount of carbohydrate intake is needed for hyper glycogen stores according to the traditional carbohydrate loading protocol.*

✗ C. 1500 g/day
   *Incorrect, please review slide Carbohydrate Loading to better understand the carbohydrate loading protocol.*

✗ D. All of the above intakes are too low
   *Incorrect, please review slide Carbohydrate Loading to better understand the carbohydrate loading protocol.*
Progress Check—Carbohydrates and Performance

3. Maximal glycogen stores are important for endurance.

✓ A. True

Correct, glycogen becomes important during high intensity and long exercise periods.

✗ B. False

Incorrect, please review slide Carbohydrate Ingestion During Exercise to better understand the role of glycogen in exercise.
General Recommendations for Carbohydrate Intake During Exercise
Carbohydrates as Energy at Different Times

- Carbohydrate consumed in the days before event
  - Used to provide adequate glycogen stores in muscle
    - Prevent “hitting the wall”

- Carbohydrate consumed in the hours before the event
  - Used to preserve liver glycogen stores, which can deplete after approximately 8 to 12 hours of fasting

- Carbohydrate consumed during event
  - Used to maintain blood glucose, especially when liver glycogen is depleted

Carbohydrates and Sports Nutrition

- Important for maximizing muscle glycogen stores
  - Depleted muscle glycogen—“Hitting the wall”
  - Depleted liver glycogen—“Bonking”

- Training and high-carbohydrate diets maximize glycogen stores

- Carbohydrates also important during recovery from exercise
  - Put back glycogen as quickly as possible
  - Glycogen synthesis is maximal within 2 hours after exercise

Carbohydrates Before Exercise

- Intake of up to 10 g/kg per day in days before event
  - Increases muscle glycogen
  - Increases endurance in events lasting > 90 minutes
- Intermittent, high-intensity exercise performance may also be increased
- Carbohydrate loading
  - No need for depletion phases common in older protocols
  - Focus now on a high-carbohydrate diet with tapered exercise
  - Men and women increase glycogen stores equally well on high-carbohydrate diet
    - Assuming energy and carbohydrate intake is sufficient

Recommendations Regarding Carbohydrate Loading

- **Day 7 before event**
  - Taper exercise

- **Days 6 to 4 before event**
  - Taper exercise
  - Moderate-carbohydrate mixed diet (5 to 7 g CHO/kg body weight/day)

- **Days 3 to 1 before event**
  - Taper exercise and/or increase rest
  - High-carbohydrate diet (8 to 12 g CHO/kg body weight/day)

Abbreviation: CHO, carbohydrate.
Carbohydrates Immediately Before Exercise

- 200 to 300 g CHO consumed after overnight fasting and 2 to 4 hours before exercise improves performance
- Ingestion of CHO 1 hour before exercise does not usually impair performance
  - Depends on individual tolerance
- GI of pre-event CHO
  - Low-GI CHO improves metabolic profile for endurance exercise
    • Effect on performance is questionable
    • Exercise itself helps blunt the insulin response
  - Effect of GI is largely obliterated if CHO is consumed during exercise¹

Abbreviations: CHO, carbohydrate; GI, glycemic index.
Pre-Competition Meal

- One of the most variable aspects of the athlete’s diet
  - Depends on individual tolerance
  - Athletes often have certain beliefs about food’s effect on performance
  - Ranges from no food to the old “steak and eggs” breakfast
  - Depends on the sport to some degree

- Functions of the pre-event meal
  - Prevent dehydration
  - Maintain adequate muscle and liver glycogen levels
  - Avoid excess hunger feelings
  - Confidence in preparation for the event

Pre-Competition Meal (continued)

- General recommendations
  - 1 to 2 cups of fluid
  - Low energy (300 to 500 kcal), larger meal if more time before event
  - High carbohydrate, low fat, moderate protein
  - Avoid excess fiber
  - 2 to 3 hours before event (perhaps 1 hour with liquid meal)
  - Liquid meals are popular for gastrointestinal comfort during the event

Examples of Pre-Competition Meals

- **Option 1**, liquid meal (blend all ingredients)\(^1\)
  - 1 cup of vanilla yogurt
  - 4 to 6 peach halves, canned or fresh
  - 4 graham cracker squares
  - Dash nutmeg, optional
  - Meal provides 450 kcal, 75% CHO, 15% protein, and 10% fat

- **Option 2**

<table>
<thead>
<tr>
<th>Food</th>
<th>Kcal</th>
<th>Carbohydrate, g</th>
<th>Protein, g</th>
<th>Fat, g</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oatmeal, instant 1 pkt</td>
<td>104</td>
<td>18</td>
<td>4</td>
<td>2</td>
</tr>
<tr>
<td>Skim milk, ½ cup</td>
<td>43</td>
<td>6</td>
<td>4</td>
<td>0</td>
</tr>
<tr>
<td>Toast, 2 slices</td>
<td>146</td>
<td>24</td>
<td>4</td>
<td>2</td>
</tr>
<tr>
<td>Banana, 1 medium</td>
<td>105</td>
<td>27</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Orange juice, 6 oz</td>
<td>84</td>
<td>20</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>TOTAL(^a)</td>
<td>482</td>
<td>95</td>
<td>13</td>
<td>5</td>
</tr>
</tbody>
</table>

\(^a\) Distribution of Kcal: CHO 80%, protein 11%, fat 9%.
Abbreviations: CHO, carbohydrate; pkt, packet.
Carbohydrates During Exercise

- Carbohydrate intake of 30 to 60 g/hour during endurance exercise
  - Consumed at 10- to 30-minute intervals
  - 1 cup of commercial sports drink has ~ 14 g (6%)
  - Liquid form of carbohydrate (ie, sports drink) also helps with hydration

- In general, do not exceed
  - 60 to 90 g/hour carbohydrate intake
    - 90 g/hour should consist of carbohydrates that use multiple transporters
  - Carbohydrate percentage > 7% to 8% in beverages
    - Due to potential for gastrointestinal distress (be aware of sugar alcohols and large amounts of fructose)
    - A matter of individual tolerance
      - Find your optimal range
      - Try first in practice, not in competition

Recommendations for Carbohydrate Intake During Postexerci
**Recommendations for Carbohydrate Intake During Postexercise Recovery (continued)**

- Carbohydrate intakes are expressed per kg,\(^a\) not % of energy
  - Immediate recovery after exercise (0 to 4 hours)
    - 1.2 g/kg/hour consumed at frequent intervals
  - Daily recovery
    - Moderate-duration/low-intensity exercise
      - 5 to 7 g/kg/day
    - Moderate to heavy endurance training
      - 7 to 12 g/kg/day
    - Extreme exercise program (≥ 4 to 6 hours/day)
      - 10 to 12+ g/kg/day

\(^a\)Multiply the numbers by 0.45 to get carbohydrate intake in grams per pound of body weight.
Recommendations for Carbohydrate Intake During Longer Recovery Periods

- During longer recovery periods (24 hours), CHO intake may be according to preferences, focus on overall amount
  - No difference between liquid and solid CHO
- CHO with moderate to high GI should be major sources of CHO in recovery meals
- Adequate energy intake, in addition to CHO, is necessary for recovery
- Do not consume excess alcohol after an event
  - May impair glycogen storage
  - Most likely interferes with ability to consume necessary CHO

Abbreviations: CHO, carbohydrate; GI, glycemic index.
Examples of Postexercise Meals

- **Option 1**
  - 1 regular bagel
  - 2T peanut butter
  - 8 fl oz skim milk
  - 1 medium banana
  - 562 kcal, 77 g carbohydrate, 23 g protein, 18 g fat

- **Option 2**
  - 17 oz commercial nutrition shake
    - 300 to 420 kcal, 17 to 70 g carbohydrate, 32 to 42 g protein, 2 to 16 g fat
Putting Together a Meal Plan

- **Example:**
  - 70-kg athlete requiring 4,000 kcal/day exercising 120 min/day for 4 to 6 times/week

- **Macronutrient target recommendations**
  - Grams/kg (body weight)/day
    - Carbohydrate 7 to 10 g/kg/day (490 to 700 g/day)
    - Protein 1.5 to 2.0 g/kg/day (105 to 140 g)
    - Fat Typically use percentage of energy as method
  - Percentage of energy
    - Carbohydrate 55% to 65% of energy (550 to 650 g/day)
    - Protein 10% to 15% of energy (100 to 150 g/day)
    - Fat 20% to 30% of energy (88 to 133 g/day)
  - Target recommendations for this athlete
    - Carbohydrate 600 g (60% of energy)
    - Protein 130 g (13% of energy)
    - Fat 120 g (27% of energy)
A Potential Distribution of Macronutrients Over the Course of 6 Meals/Day

<table>
<thead>
<tr>
<th>Meal</th>
<th>Time</th>
<th>Carbohydrate, g</th>
<th>Protein, g</th>
<th>Fat, g</th>
</tr>
</thead>
<tbody>
<tr>
<td>Breakfast</td>
<td>7:00 AM</td>
<td>90</td>
<td>15</td>
<td>15</td>
</tr>
<tr>
<td>Mid-morning snack</td>
<td>10:00 AM</td>
<td>25</td>
<td>10</td>
<td>5</td>
</tr>
<tr>
<td>Lunch</td>
<td>Noon</td>
<td>75</td>
<td>20</td>
<td>20</td>
</tr>
<tr>
<td>Pre-exercise meal</td>
<td>1:30 - 2:00 PM</td>
<td>90</td>
<td>10</td>
<td>5</td>
</tr>
<tr>
<td>During exercise</td>
<td>3:00 - 5:00 PM</td>
<td>100</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Post-exercise meal</td>
<td>5:00 PM</td>
<td>75</td>
<td>30</td>
<td>25</td>
</tr>
<tr>
<td>Dinner</td>
<td>6:30 PM</td>
<td>120</td>
<td>30</td>
<td>35</td>
</tr>
<tr>
<td>Evening snack</td>
<td>9:00 PM</td>
<td>25</td>
<td>15</td>
<td>15</td>
</tr>
<tr>
<td>TOTALS</td>
<td></td>
<td>600</td>
<td>130</td>
<td>120</td>
</tr>
</tbody>
</table>
Foods Containing Approximately 25 to 30 g Carbohydrate

- 1 cup of juice or 1 large piece of fruit
- 1 bagel or 2 slices of bread
- 1 cup of most cereals
- 1 large baked potato
- 2 cups of milk
- ⅓ cup of dried beans
- 1 cup of rice or corn
- 1 cup of squash (other non-starchy vegetables have less carbohydrate)
- 2 cups of commercial sports/electrolyte replacement drink
- ½ to 1 energy bar (1 bar ≈ 25 to 45 g carbohydrate)
- 1 pack of an energy gel (≈ 25 g carbohydrate)

Progress Check—Competitions

1. A total of 200-300 g carbohydrate consumed 2-4 hours before exercise generally improves performance.
   A. True
   B. False

2. Which of the following is a benefit of a pre-competition meal?
   A. Improved flexibility
   B. Reduced stress
   C. Improved immune system
   D. Improved hydration
   E. All of the above

3. When consuming carbohydrates during endurance exercise, it is best not to exceed what intake level?
   A. 10 to 19 g/hr
   B. 20 to 39 g/hr
   C. 40 to 59 g/hr
   D. 60 to 90 g/hr
Progress Check—Competitions

1. A total of 200-300 g carbohydrate consumed 2-4 hours before exercise generally improves performance.

✓ A. True
Correct, consuming 200-300 g of carbohydrates just prior to exercise can improve performance.

✗ B. False
Incorrect, please review slide Carbohydrates Immediately Before Exercise to better understand carbohydrate consumption before exercising.
2. Which of the following is a benefit of a pre-competition meal?

A. Improved flexibility
   *Incorrect, please review slides on Pre-Competition Meal to better understand the benefits of a pre-competition meal.*

B. Reduced stress
   *Incorrect, please review slides on Pre-Competition Meal to better understand the benefits of a pre-competition meal.*

C. Improved immune system
   *Incorrect, please review slides on Pre-Competition Meal to better understand the benefits of a pre-competition meal.*

D. Improved hydration
   *Correct, preventing dehydration, maintaining adequate muscle and liver glycogen levels, and avoiding excess hunger feelings are all benefits of a pre-competition meal.*

E. All of the above
   *Incorrect, please review slides on Pre-Competition Meal to better understand the benefits of a pre-competition meal.*
3. When consuming carbohydrates during endurance exercise, it is best not to exceed what intake level?

× A. 10 to 19 g/hr  
Incorrect, please review slide Carbohydrates During Competition to better understand the recommended carbohydrate intakes during exercise.

× B. 20 to 39 g/hr  
Incorrect, please review slide Carbohydrates During Competition to better understand the recommended carbohydrate intakes during exercise.

× C. 40 to 59 g/hr  
Incorrect, please review slide Carbohydrates During Competition to better understand the recommended carbohydrate intakes during exercise.

✓ D. 60 to 90 g/hr  
Correct, it is recommended to not exceed a carbohydrate intake of 90 g/hr.
Summary of Key Messages

- Knowledge of the glycemic index of carbohydrates can be helpful in choosing the right carbohydrate at the right time.
- Consuming carbohydrate during exercise also generally helps performance:
  - Experiment in practice regarding tolerated levels.
  - Liquid carbohydrates also help with hydration.
- Eating as soon as possible after exercise promotes the most rapid recovery of muscle glycogen:
  - Combination of carbohydrate and protein may facilitate this process.
- Frequent, smaller meals can help athletes with high energy and carbohydrate requirements obtain the required amounts of nutrients.
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