CARBOHYDRATES: TYPES & ABSORPTION RELATED TO EXERCISE
OVERVIEW

• Review the importance of carbohydrates for athletes

• Structure and classifications

• Oxidation rates of different carbohydrates

• Absorption
Carbohydrates are the primary fuel for muscle contraction.
CONSUMING CARBOHYDRATES WILL...

- Maintain high rates of carbohydrate oxidation
- Reduce ratings of perceived exertion
- Increase endurance capacity
- Delay the onset of fatigue
- Prevent hypoglycemia
CARBOHYDRATE
DEFINED
An organic compound made of carbon, hydrogen and oxygen.

A class of food that is rich in sugars, starches, or fibers.

An individual carbohydrate is classified as a sugar, starch, or fiber depending on the structure and number of glucose molecules.
CARBOHYDRATE CLASSIFICATIONS

Simple Carbohydrates (Sugars)

Complex Carbohydrates (Starches/Fibers)

monosaccharide

disaccharide

polysaccharide/glucose polymer
Monosaccharides

- glucose
- fructose
- galactose
CARBOHYDRATE CLASSIFICATIONS

Disaccharides

- Sucrose
- Lactose
- Maltose
Polysaccharides

amylose

amylopectin
Maltodextrin

- Group of glucose polymers
- Produced from potato or corn starch
- Same oxidation rate as glucose and sucrose
- Common carbohydrate source in sports nutrition products
CARBOHYDRATE CLASSIFICATIONS

Mono
- Glucose
- Fructose
- Galactose

Di
- Sucrose
- Lactose
- Maltose

Poly
- Starch
  - Amylose
  - Amylopectin
- Fiber
  - Soluble
  - Insoluble
CARBOHYDRATE CLASSIFICATIONS

Mono

Di

Poly
Oral receptors in the mouth detected ingested carbohydrate, can improve exercise performance.

Digestion to monosaccharides

Absorption via glucose & fructose transporters

Fuel for brain & muscle

Carbohydrates are often classified as “simple” and complex” based on their structures.

But, this chemical classification doesn’t reflect the physiology of the carbohydrate in the body.

Rather than simple/complex, choice of carbohydrate for athletes during exercise should be based on oxidation rate, which is determined by absorption at the intestine.
<table>
<thead>
<tr>
<th>SIMPLE</th>
<th>COMPLEX</th>
</tr>
</thead>
<tbody>
<tr>
<td>Glucose</td>
<td>Amylose</td>
</tr>
<tr>
<td>Fructose</td>
<td>Amylopectin</td>
</tr>
<tr>
<td>Galactose</td>
<td></td>
</tr>
<tr>
<td>Sucrose</td>
<td></td>
</tr>
<tr>
<td>Maltose</td>
<td></td>
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</tbody>
</table>
**TYPES OF CARBOHYDRATES**

<table>
<thead>
<tr>
<th>FASTER</th>
<th>SLOWER</th>
</tr>
</thead>
<tbody>
<tr>
<td>Glucose</td>
<td>Fructose</td>
</tr>
<tr>
<td>Maltose</td>
<td>Galactose</td>
</tr>
<tr>
<td>Sucrose</td>
<td>Trehalose</td>
</tr>
<tr>
<td>Maltodextrins</td>
<td>Isomaltulose</td>
</tr>
<tr>
<td>Amylopectin</td>
<td>Amylose</td>
</tr>
</tbody>
</table>

- **FASTER Absorption**
  - 1.0 g/min (60 g/h)
- **SLOWER Absorption**
  - 0.06 g/min (35 g/h)

| Source | Jeukendrup A. Sports Science Exchange, 2007;20(3)1-6 |
✔ When practicing or competing for an hour or longer

✔ Goal = Performance

✔ 30-60 g/h

✔ Easily digestible, quickly oxidized carbohydrate
A faster rate of carbohydrate oxidation can result in a better performance.
OXIDATION RATES DURING CYCLING

120 min @ 65% max
60 min rest
30 min @ 60% max

8% $^{13}$C-enriched glucose –or- galactose

8mL/kg pre
2 mL/kg every 15 min

Leijssen et. al. JAP. 1995;79:720-725
Intestinal wall has transporters for both glucose and fructose.

Making use of both transporters increases carbohydrate absorption and oxidation.
Toll Booth Analogy

Think of the carbohydrate transporters each as a lane of a toll booth

The more toll lanes that are open, the faster the cars can move through

If less toll lanes are open for use, the cars can get backed up
You don’t need all “fast” sugars

FRUCTOSE + GLUCOSE

FRUCTOSE + GLUCOSE COMBINATION

<table>
<thead>
<tr>
<th>Total CHO Oxidation (g/min)</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.00</td>
</tr>
</tbody>
</table>

Lecoultre et al. AJCN. 2010;92:1071-1079
Endurance activities > 2.5 hours

Aim for 90 g/h, use multiple transporters

The CHO source should be a mix of glucose and fructose in a ratio of roughly 2:1.

60 g/h of glucose (to saturate the SGLT1 transporters) and 30 g/h of additional fructose for oxidation.
## Common Sugars in Sports Nutrition Products

<table>
<thead>
<tr>
<th>Dietary Sugar Source</th>
<th>After digestion:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Glucose</td>
<td>Glucose</td>
</tr>
<tr>
<td>Sucrose</td>
<td>Glucose + Fructose</td>
</tr>
<tr>
<td>Maltodextrin</td>
<td>Glucose</td>
</tr>
<tr>
<td>High Fructose Corn Syrup</td>
<td>Glucose + Fructose</td>
</tr>
<tr>
<td>Organic Cane Sugar, Honey, Molasses, Agave nectar, Fruit juice concentrate</td>
<td>Glucose + Fructose</td>
</tr>
</tbody>
</table>
Sugar Gets a Bad Rap

Sugar is often demonized and called “toxic”

Many quickly oxidized carbohydrates are sugars

For athletes, it’s important to differentiate the need for a *functional CHO* (sugar) *during* exercise due to fast absorption and oxidation – it won’t provide energy if it’s sitting in the gut causing GI upset!
For sports nutrition needs (pre/during/post exercise) the focus should be on quickly oxidized CHO.

Throughout the rest of the day, athletes should focus on nutrient-rich sources regardless of oxidation rate, including *fruits, vegetables, whole grains and legumes.*

25-30 g/d = recommended fiber intake from food.
ZERO CALORIES

ZERO ENERGY

ARTIFICIAL SWEETENERS
Carbohydrates are the primary fuel for muscle contraction.

Intake during exercise can help improve performance.

The chemical classification (simple/complex) does not reflect the physiologic response in the body.

During exercise, consume mostly “fast” carbohydrates – those that are quickly oxidized.

Multiple transportable carbohydrates.