Fueling During Exercise

for Female Athletes

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Introduction

Fueling optimally during exercise can help athletes to increase exercise capacity, improve exercise performance and skill execution, and delay fatigue. It is important for female athletes to understand how they can meet fueling requirements, which differ depending on exercise duration and intensity. The information below will explain key considerations for fueling during exercise. It should be noted that the recommendations currently do not differ between females and males.

Fuel use during exercise

Carbohydrate and fat are both important fuels during exercise, with the contribution of carbohydrate to energy metabolism increasing as exercise intensity increases. There are limited stores of endogenous carbohydrate (i.e., glycogen) within the body, and these stores reduce during exercise when they are used for energy. Glycogen stores will become reduced at a quicker rate during higher intensity exercise (Figure 1), which limits the rate of carbohydrate oxidation. Consuming carbohydrate during exercise (i.e., exogenous carbohydrate) provides additional fuel to be used, which helps to maintain carbohydrate oxidation rates, and in turn delay fatigue and maintain performance.

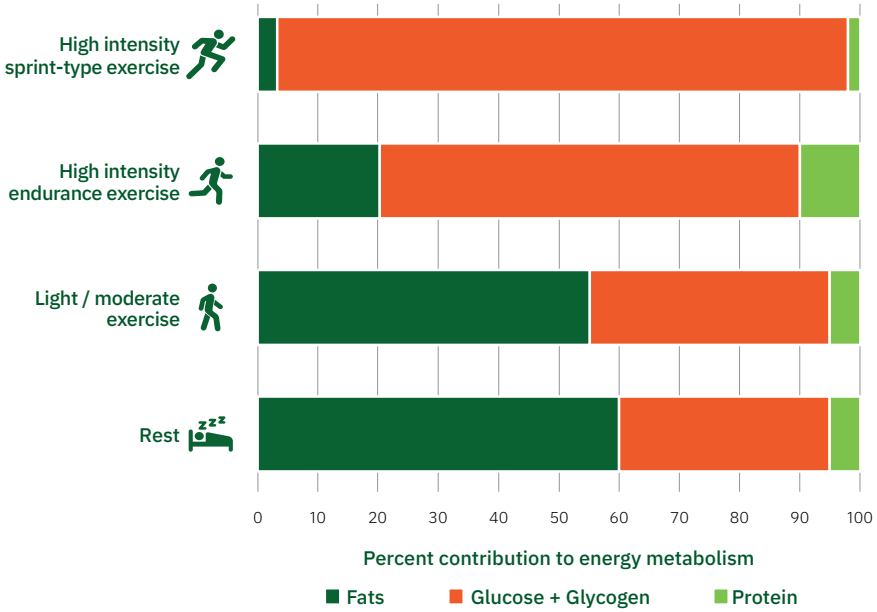


Figure 1: Substrate metabolism at rest and during different exercise types and intensities

Potential benefits of optimal fueling during exercise

- **Increased exercise capacity**
- **Improved performance**
- **Maintain carbohydrate oxidation**
- **Prevent hypoglycemia**

Carbohydrate oxidation rates: females vs males

Research has found that females have lower rates of carbohydrate oxidation and higher rates of fat oxidation during fasted endurance exercise compared to males. These sex differences in substrate metabolism might be due to many factors such as higher maximal oxygen uptake, greater muscle mass, and lower estrogen levels in males, although the exact mechanisms remain unclear. However, when carbohydrate is consumed during exercise, these sex differences in substrate metabolism are not seen. In other words, both males and females oxidize ingested carbohydrate at the same rate. Therefore, currently there are no sex-specific carbohydrate recommendations for during exercise.

Carbohydrate recommendations during exercise

Exercise duration:

< 30 minutes

No carbohydrate necessary

During exercise that is < 30 minutes, muscle glycogen is not a limiting factor for performance. It is therefore not necessary for athletes to consume carbohydrate during exercise lasting < 30 minutes, especially if they are optimally fueled beforehand, or have time to refuel post-exercise.

Exercise duration:

30-75 minutes

Small amount of carbohydrate OR carbohydrate mouth rinse

During exercise lasting 30-75 minutes, athletes may benefit from either a small amount of carbohydrate intake, or a carbohydrate mouth rinse, especially if the exercise is high intensity. Carbohydrate mouth rinsing involves athletes swilling a carbohydrate-containing solution in their mouth (e.g., a sports drink) for 5-10 seconds, which they then spit out. The exact mechanisms remain unclear, but it is likely that the carbohydrate (energy) is detected by receptors in the oral cavity, which activates certain brain regions, causing improved motor drive and/or motivation. During shorter duration exercise bouts, carbohydrate mouth rinsing has been shown to produce very similar performance improvements as those seen when the carbohydrate is actually consumed. The choice between swallowing the carbohydrate solution or expectorating the solution depends on the practicalities of the sport the athlete is competing in, as well as individual preferences.

Exercise duration:

1-2 hours

30-60 grams of carbohydrate per hour

There is extensive research to show that during exercise lasting 1-2 hours, consuming 30-60 grams of carbohydrate per hour (g/h) can improve performance. If the exercise is longer in duration (e.g., close to 2 hours) and/or high intensity, then athletes should aim for the upper end of the recommendation. When athletes are consuming carbohydrate at a rate of < 60 g/h, single sources of rapidly oxidized carbohydrate (e.g., glucose or sucrose) can be ingested.

Exercise duration:

2-3 hours

60-90 grams of carbohydrate per hour

Carbohydrate intake becomes even more important when exercise duration extends beyond 2 hours, in order to prevent a decrease in performance. It is recommended that athletes consume carbohydrate at rates > 60 g/h, and up to 90 g/h for exercise durations > 2.5 hours. This should be in the form of multiple transportable carbohydrates (see below).

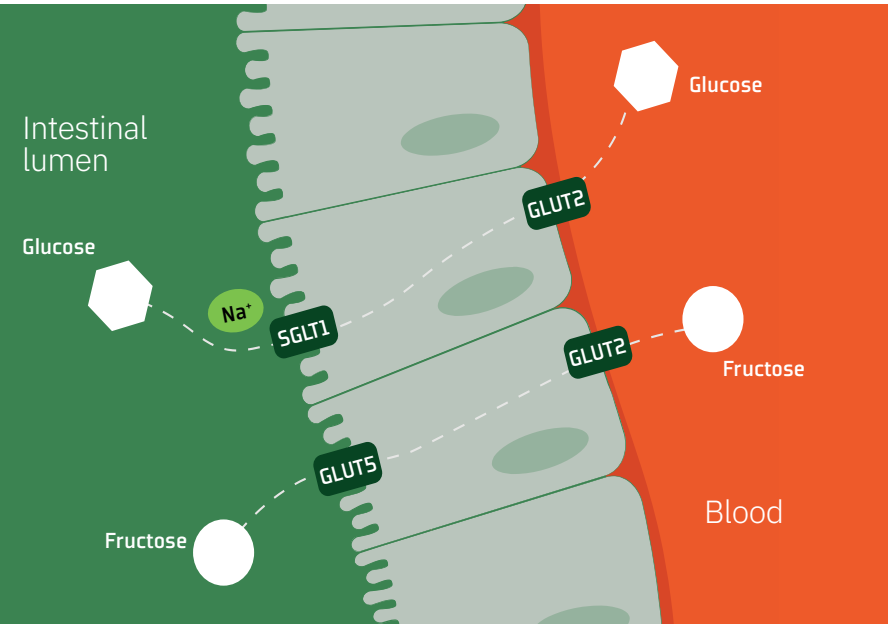
Multiple transportable carbohydrates explained

Carbohydrates are taken up and absorbed by the body using a variety of transporters located in the intestines. However, exogenous carbohydrate oxidation is limited by the rate at which carbohydrates can be absorbed, with intestinal transporters becoming saturated at carbohydrate intakes of ~60 g/h. Therefore, when carbohydrate is consumed at a rates of up to 60 g/h, single sources of carbohydrate can be utilized (e.g., glucose, sucrose).

Consuming multiple transportable carbohydrates (i.e., carbohydrates which use different intestinal transporters), like glucose and fructose, can enhance carbohydrate absorption and utilization compared to a single carbohydrate source. For example, glucose and fructose use different intestinal transporters: glucose uses sodium-glucose cotransporter 1 (SGLT1), which is independent of the transporter that fructose uses, glucose transporter 5 (GLUT5). Therefore, co-ingesting carbohydrates that use different transporters results in higher total carbohydrate oxidation rates, which is beneficial for prolonged or intense endurance exercise (i.e., when carbohydrate intakes of > 60 g/h are required). In addition, ingesting multiple transportable carbohydrates has been shown to increase fluid intake in the intestine in comparison to ingesting a single carbohydrate source.

Absorption of glucose and fructose

In practical terms, it is recommended that athletes consume a 2:1 ratio of glucose:fructose when consuming carbohydrate at rates > 60 g/h. This can be achieved by consuming sports drinks or gels which contain a combination of glucose and fructose. Overall, consuming multiple transportable carbohydrates is an effective strategy for maximizing carbohydrate utilization for prolonged exercise.



Carbohydrate intake recommendations during exercise

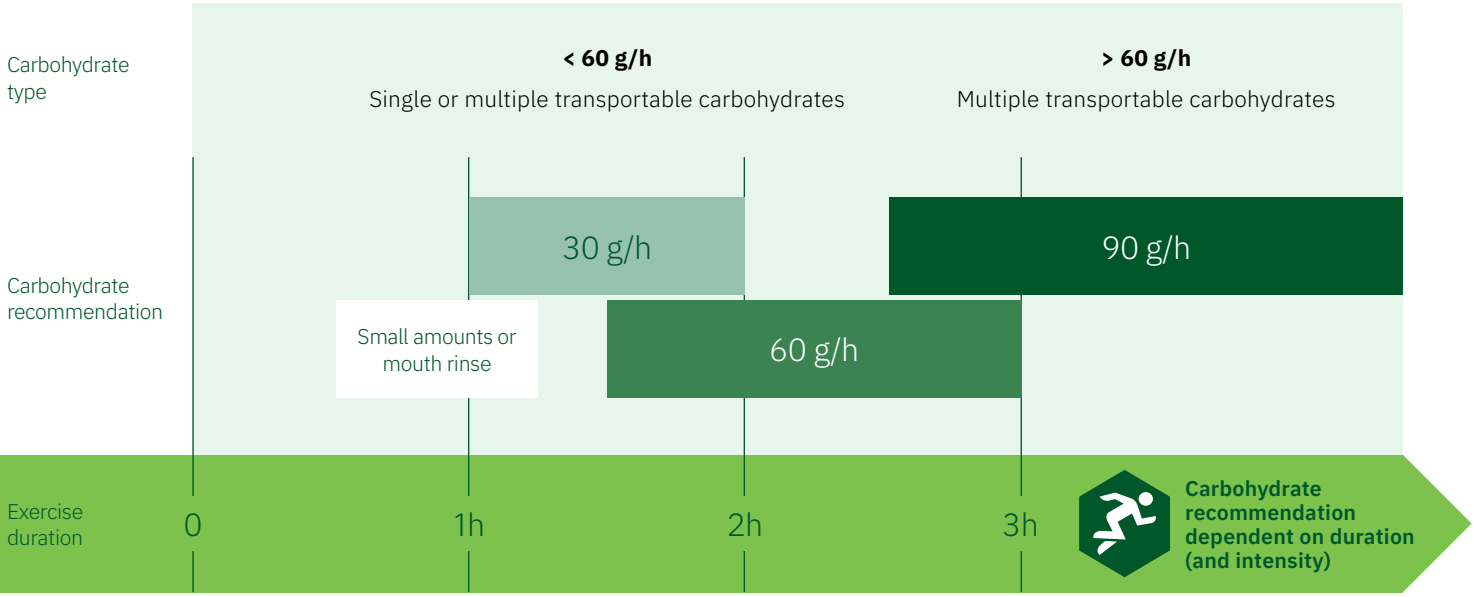


Figure 2: Carbohydrate intake recommendations during exercise
Adapted from Jeukendrup (2014)

Sources of carbohydrate

Carbohydrate can be consumed during exercise in a variety of forms (Figure 3), with no differences in carbohydrate oxidation or performance outcomes seen between different forms. If a solid food option is chosen, then it should ideally be low in fat, protein, and fiber to avoid any gastrointestinal issues.

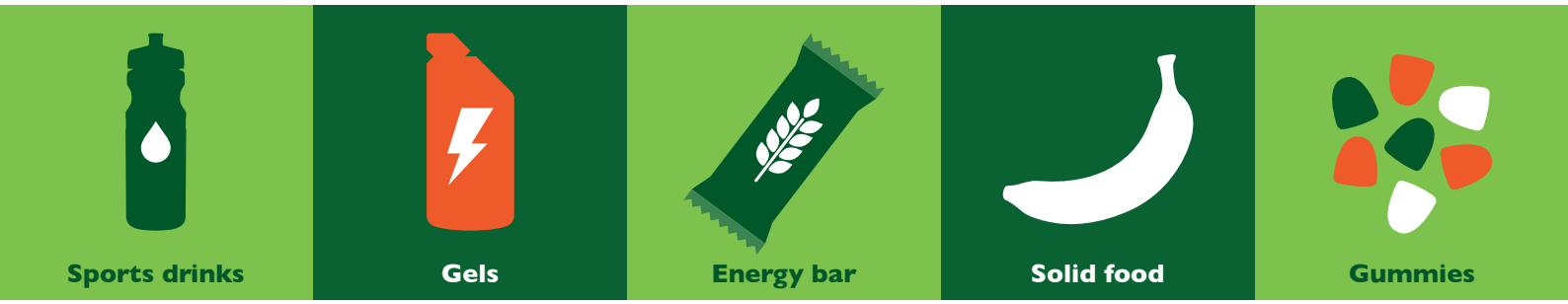


Figure 3: Different forms of carbohydrate

Gastrointestinal complaints during exercise

It has been shown that ~30-50% of athletes experience gastrointestinal complaints during exercise. Early research suggested that prevalence of exercise-associated gastrointestinal symptoms was greater in female athletes vs. male athletes. However, more recent investigations have not seen any differences between genders. Gastrointestinal complaints can be classified into upper and lower abdominal symptoms:

Upper abdominal symptoms	Lower abdominal symptoms
Reflux/heartburn	Intestinal/lower abdominal cramps
Belching	Side ache/stitch
Bloating	Flatulence
Stomach pain/cramps	Urge to defecate
Vomiting	Diarrhea
Nausea	Intestinal bleeding

Potential causes

There are three potential causes of gastrointestinal symptoms during exercise which are:

Physiological (reduced blood flow to the gut)

Mechanical (repetitive gut jostling e.g., running)

Nutritional

Nutritional causes can include:

- Consuming high fiber foods too close to exercise may lead to bloating, gas and abdominal cramps as the fiber is poorly digested and absorbs water in the gut.
- High fructose ingestion from sports drinks, gels and chews can result in abdominal cramps, bloating and diarrhea.
- The osmolality and carbohydrate concentration of some carbohydrate-containing drinks can delay gastric emptying and draw fluid into the gut, potentially contributing to reflux and nausea.

Training the gut

The gastrointestinal tract is crucial for delivering ingested carbohydrate and fluids to the body during exercise. It has been demonstrated that the gastrointestinal system is highly adaptable and that both gastric emptying (the rate at which food and fluids empty from the stomach) and stomach comfort can be 'trained' over time through various methods. Training the gut can indirectly improve performance by effectively absorbing and metabolizing carbohydrates and also reducing any gastrointestinal discomfort experienced by athletes. Figure 4 shows various methods which can be used to train the gut, along with their physiological effects.

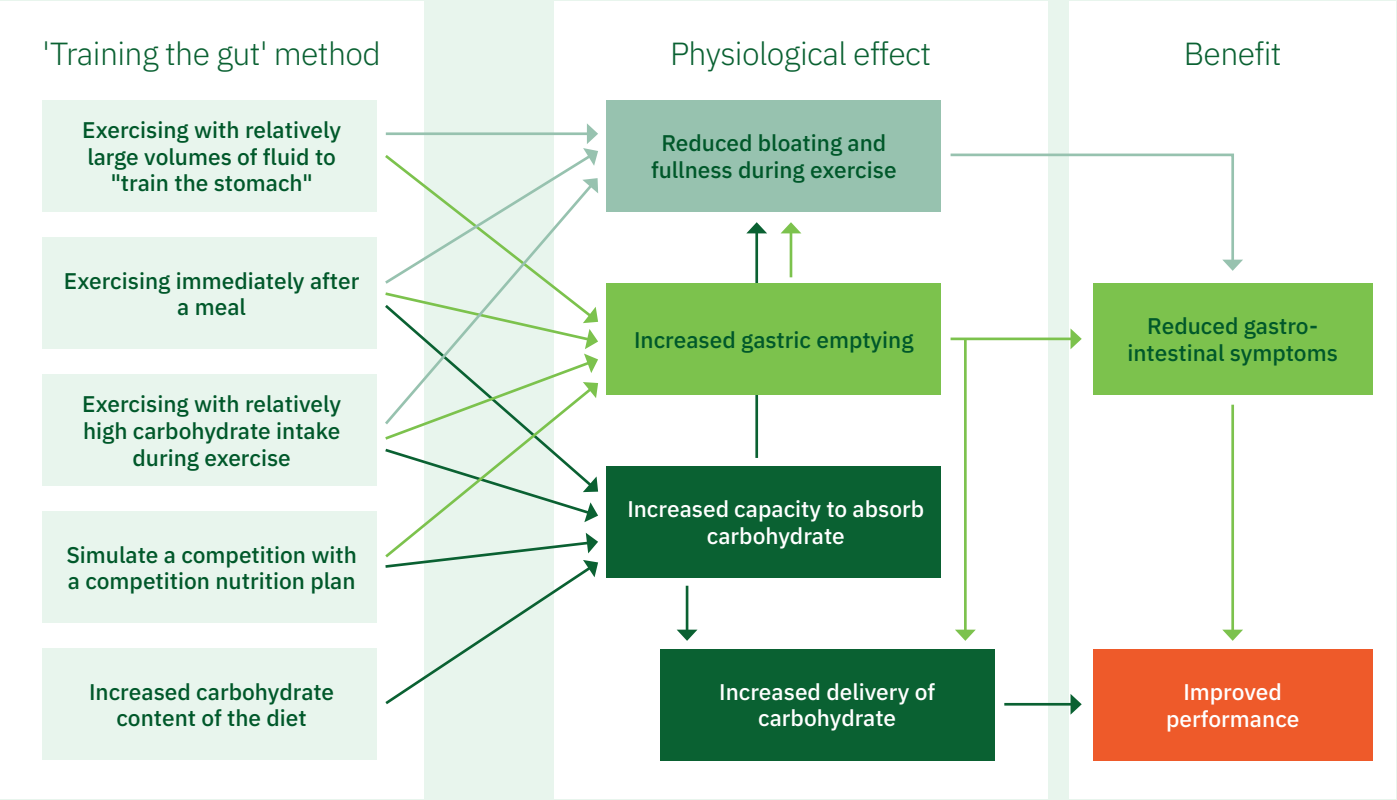


Figure 4: Methods for 'Training the gut'
Adapted from Jeukendrup (2014)

Considerations

Athletes should be encouraged to practice their competition nutrition strategy prior to a competition, especially if the exercise duration is prolonged, so that they can become familiar with higher carbohydrate intakes.

Athletes who have a low consumption of carbohydrate e.g., those following a low-carbohydrate, high fat or ketogenic diet, or those who are reducing daily energy intake to lose weight, will have a reduced capacity to absorb carbohydrates during exercise.

Encourage athletes to regularly practice consuming carbohydrate during exercise, including high carbohydrate intakes during prolonged exercise.

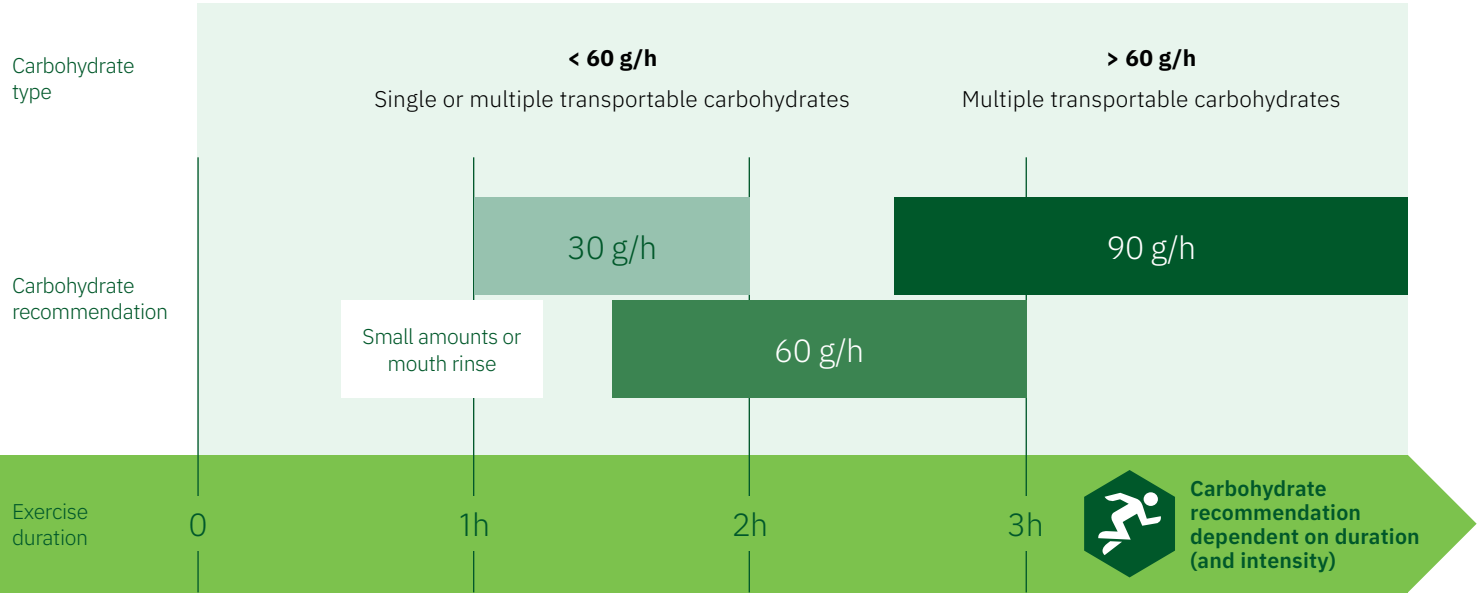
FUELING DURING EXERCISE

Potential benefits of optimal fueling during exercise

- **Increased exercise capacity**
- **Improved performance**
- **Maintain carbohydrate oxidation**
- **Prevent hypoglycemia**

Carbohydrate recommendations for different exercise durations

< 30 minutes	30-75 minutes	1-2 hours	2-3 hours
No carbohydrate necessary	Small amount of carbohydrate OR carbohydrate mouth rinse	30-60 grams of carbohydrate per hour	60-90 grams of carbohydrate per hour



Fuel sources during exercise

- **Sports drinks**
- **Gels**
- **Energy bar**
- **Solid food**
- **Gummies**

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References and resources

Burke, L. M., Hawley, J. A., Wong, S. H. S., & Jeukendrup, A. E. (2011). Carbohydrates for training and competition. Journal of Sports Sciences, 29 Suppl 1, S17-27.

Jeukendrup, A. E. (2007). Carbohydrate supplementation during exercise: Does it help? How much is too much? GSSI Sports Science Exchange #106.

Jeukendrup, A. E., Rollo, I. & Carter, J. M. (2013). Carbohydrate mouth rinse: Performance effects and mechanisms. GSSI Sports Science Exchange #118.

Jeukendrup, A. (2014). A step towards personalized sports nutrition: Carbohydrate intake during exercise. Sports Medicine, 44 Suppl 1(Suppl 1), S25-33.

Podlogar, T., & Wallis, G. A. (2022). New Horizons in Carbohydrate Research and Application for Endurance Athletes. Sports Medicine, 52(Suppl 1), 5–23.

Pugh, J. N., Lydon, K. M., O'Donovan, C. M., O'Sullivan, O., & Madigan, S. M. (2022). More than a gut feeling: What is the role of the gastrointestinal tract in female athlete health? European Journal of Sport Science, 22(5), 755–764.

Rollo, I., Cole, M., Miller, R., & Williams, C. (2010). Influence of mouth rinsing a carbohydrate solution on 1-h running performance. Medicine and Science in Sports and Exercise, 42(4), 798–804.

Rollo, I., Gonzalez, J. T., Fuchs, C. J., van Loon, L. J. C., & Williams, C. (2020). Primary, Secondary, and Tertiary Effects of Carbohydrate Ingestion During Exercise. Sports Medicine, 50(11), 1863–1871.