Fueling Before, During and After Exercise

Consuming carbohydrate prior to exercise can help performance by "topping off" muscle and liver glycogen stores. Consuming carbohydrate during exercise can improve performance by maintaining blood glucose levels and carbohydrate oxidation. Finally, ingesting carbohydrate after glycogen-depleting exercise facilitates rapid glycogen restoration, especially among athletes engaged in daily hard training or tournament activity.

Pre-exercise meal

Consuming carbohydrate-rich foods and fluids in the four hours before exercise helps to: restore liver glycogen, especially for morning exercise when liver glycogen is depleted from an overnight fast; increase muscle glycogen stores if they are not fully restored from the previous exercise session; ensure the athlete is hydrated; prevent hunger, which may in itself impair performance; and give the athlete a psychological boost (1).

Consuming carbohydrate on the morning of an endurance event may help to maintain blood glucose levels during prolonged exercise. Including some low-glycemic index foods may be beneficial in promoting a sustained release of glucose into the bloodstream (1).

The research suggests that the pre-exercise meal contain 1 to 4.0 gm of carbohydrate/kg, consumed one to four hours prior to exercise (2,3,4). To avoid potential gastrointestinal distress when blood is diverted from the gut to the exercising muscles, the carbohydrate and calorie content of the meal should be reduced the closer to exercise the meal is consumed. For example, a carbohydrate feeding of 1 gm/kg is appropriate an hour

before exercise, whereas 4.0 gm/kg can be consumed four hours before exercise (4).

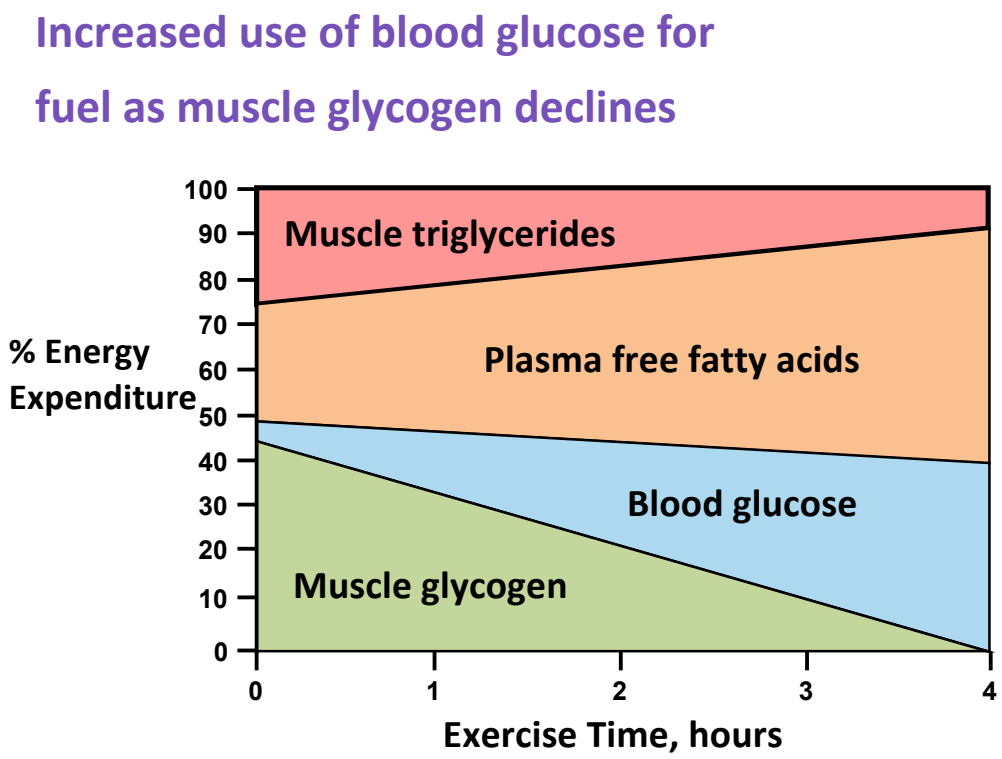
Carbohydrate, g/kg	Timing Prior to Exercise, hours
1.0	1
2.0	2
3.0	3
4.0	4

Good examples carbohydrate-rich foods for pre-exercise meals include fruit, cereal, bread products (adding jam or jelly increases the carbohydrate content) and low-fat or nonfat yogurt. Fruit juices and nonfat milk are good carbohydrate-rich beverages. The athlete may also incorporate liquid meals or high carbohydrate liquid supplements.

Consuming carbohydrate in the hour before exercise can cause rebound hypoglycemia (a rapid decrease in blood glucose levels), in most cases, the decline in blood glucose observed during the first 20 minutes of exercise is self-correcting with no apparent effects on the athlete (1).Pre-exercise carbohydrate feedings either improve performance by 7 to 20 percent or have no detrimental effect (1).

Fueling during exercise

Consuming carbohydrate during exercise lasting one hour or more can delay the onset of fatigue and improve endurance capacity by maintaining blood glucose levels and carbohydrate oxidation in the latter stages of exercise (4,5,6,7). Carbohydrate feedings may also improve performance in stop-and-go sports such as basketball, soccer, football, and tennis that require repeated bouts of high-intensity, short-duration effort (4,8).



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Carbohydrate absorption and oxidation as well as endurance performance can be increased by using a mixture of carbohydrates that use different intestinal transporters for absorption (9,10). Liquid (e.g. sports drink) and solid carbohydrates (e.g. sports bar and gel) are equally effective in increasing blood glucose and improving performance (11,12).

The recommendations for carbohydrate intake during exercise can be absolute (g per hour) and not based on body weight (4,9). Consuming carbohydrate is neither practical nor necessary during exercise lasting less than 45 minutes (4). Small amounts of carbohydrate from sports drinks or foods may enhance performance during sustained high-intensity exercise lasting 45 to 75 minutes (4). Athletes should consume 30 to 60 g of carbohydrate per hour from carbohydrate-rich fluids or foods during endurance and

intermittent, high intensity exercise lasting 1 to 2.5 hours (4). As the duration of the event increases, so does the amount of carbohydrate required to enhance performance (4). During endurance and ultra-endurance exercise lasting 2.5 to 3 hours and beyond, athletes should consume up to 80 to 90 g of carbohydrate per hour (4,9). Products providing multiple transportable carbohydrates are necessary to achieve these high rates of carbohydrate oxidation (4,9). Athletes should individually determine a refueling plan that meets their nutritional goals (including hydration) and minimizes gastrointestinal distress (4).

Exercise lasting less than 45 minutes	Not necessary or practical
High-intensity exercise lasting 45 to 75 minutes	Small amounts of sports drinks or foods
Endurance and intermittent, high intensity exercise lasting 1 to 2.5 hours	30 to 60 g per hour
Endurance and ultra-endurance exercise lasting 2.5 to 3 hours and beyond	Up to 80 to 90 g per hour

Carbohydrate content of selected foods:

1 quart of sports containing 6 to 8 percent carbohydrate = 60 to 76 g

1 high-carbohydrate sports bar = 40 to 45 g

2 energy gels = 44 to 50 g

10 large jelly beans (1 oz) = 26 g

3 large graham crackers = 66 g

4 fig cookies = 42 g

1 banana = 30 g

Recovery nutrition

Utilizing effective refueling strategies following daily training sessions helps to optimize recovery and promote the desired adaptations to training. When there is less than 8 hours between workouts or competitions that deplete muscle glycogen stores, the athlete should start consuming carbohydrate *immediately* after the first exercise session to maximize the effective recovery time between sessions. The athlete should consume 1 to 1.2 g of carbohydrate/kg per hour for the first four hours after glycogen-depleting exercise. Consuming small amounts of carbohydrate frequently – every 15-30 minutes – further enhances muscle glycogen synthesis (4, 13, 14,15).

During longer periods of recovery (24 hours), it doesn't matter how carbohydrate intake is spaced throughout the day as long as the athlete consumes adequate carbohydrate and energy. The type, pattern, and timing of carbohydrate intake can be chosen according to what is practical and enjoyable (4).

Carbohydrate-rich foods with a moderate to high glycemic index should be emphasized in recovery meals/snacks to supply a readily available source of carbohydrate for muscle glycogen synthesis (15).

Recommendations for carbohydrate intake after glycogen-depleting exercise:

- When less than 8 hours between exercise sessions, start consuming carbohydrate immediately after exercise to maximize recovery time

- Consume 1 to 1.2 g of carbohydrate/kg/hour for the first four hours after glycogen-depleting exercise
- Early refueling may be enhanced by consuming small amounts of carbohydrate more frequently – e.g., every 15-30 minutes
- Choose medium– to high–glycemic index foods.

Adding protein to the recovery feeding does not enhance muscle glycogen storage when the amount of carbohydrate is at or above the threshold for maximum glycogen synthesis — 1 to 1.2 gm/kg/hour (15). However, adding a small amount of protein (~0.3 g/kg/hour) to a suboptimal carbohydrate intake (< 1 g/kg/hour) can accelerate muscle glycogen restoration (16).

Consuming protein with recovery snacks and meals also helps to increase net muscle protein balance, promote muscle tissue repair, and enhance adaptations involving synthesis of new proteins (17). The athlete's initial recovery snack/meal should include 15 to 25 g of high quality protein in addition to carbohydrate (4,18). This can be provided by 16 ounces of skim milk (16 g), two to three large eggs (14-21 g) or two to three ounces of lean red meat (14-21 g).

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