Intro: Energy for endurance exercise is primarily fueled by fats and carbohydrates, with carbohydrate utilization increasing as the intensity of the exercise increases. Thus, carbohydrates are crucial to competitive endurance exercise performance. In addition to food based carbohydrates, there are many different energy supplements marketed for sport, which are available in a variety of forms. These carbohydrate supplements are available as a result of demand based upon experiential and research based evidence, but understanding when your body needs each carb and in which amount depends on three key areas: capacity, conversion and type.

Capacity: At rest, the human body typically has enough carbohydrates to fuel 3 hrs of exercise at a rate of 10kcal/hr which includes blood, muscle, and liver glycogen stores totaling 1,520 to 2,020kcal. The conversion of carbohydrates to energy is highly efficient compared to fats and protein. Thus, carbohydrates are a great fuel source, but our storage capacity, even with training, is generally insufficient to meet the demands of competitive endurance sports.

Conversion: The ability to rapidly replenish carbohydrates after training, and the ability to consume and convert ingested carbohydrates into a usable form of carbohydrate is important in allowing you to train and compete at your best. Ingestion of the wrong carbohydrates at the wrong time, or ingesting too little carbohydrate can impair performance both in the short term and long term.

Type: The biochemical structure of the carbohydrate, the absorption process, the size of the food particle, the degree of processing, the contents and timing of the previous meal, and the co-ingestion of fat, fiber, or protein affect a carbohydrates absorption and glycemic index. (Guezennec, 1995)

What exactly is the glycemic index? Based on a 50g-portion size, the glycemic index (GI) of a carbohydrate represents the magnitude of the increase in blood sugar that occurs after ingestion of the carbohydrate. What glycemic index does not define is the portion size of the carbohydrate meal ingested (whether the portion size is 5g or 500g GI is not affected), but portion size can affect blood sugar. Carbohydrates with a higher GI cause a higher rush of sugar into your blood than carbohydrates with low GI. Elevated blood sugar causes insulin to be secreted to help modulate the sugar and subsequent sugar crash follows. Glycemic Load measures the GI multiplied by the total carbohydrate content giving a more practical and accurate determination of blood sugar response. A complete list of GI for foods can be found at http://www.mendosa.com/advanced_GI_GL_data.xls

How do sugars differ? Conventional wisdom says that since all carbohydrates are
Eventually digested and absorbed as glucose, the original food source of the sugar, whether a bean or a candy bar, matters little. Sugar is sugar. Sucrose is sucrose. Not exactly!

**Fructose** has a GI of 20±5 and is a simple sugar (monosaccharide) like glucose and galactose. Natural sources of fructose include honey and fruits. Fructose is 75% sweeter than glucose and is generally found in honey and fruits in addition to its many uses as a food-sweetening additive. It is often preferred over straight glucose and sucrose as an energy source, since it is absorbed more slowly into the bloodstream and, therefore, has a less erratic effect on blood sugar levels. Diabetics or those that are very sensitive to changes in blood sugar find fructose to be advantageous. But, as a result of its slow absorption, beverages that contain only fructose can cause gastric upset. Research suggests that fructose is more tolerable when combined with sucrose and glucose. Avoid beverages that list “high fructose corn syrup” as primary ingredients as they will slow fluid uptake and not provide optimal sugars to support exercise energy requirements.

**Galactose** is a simple sugar that has recently shown up in sports drinks. Lactose is the primary sugar in dairy products and is composed of one molecule of glucose and one of galactose. Because of its galactose content, it is more slowly absorbed into the bloodstream than pure glucose and is therefore more blood-sugar-friendly. *The GI of Galactose could not be found on any of the official GI lists, though G-Push (a popular sports drink) does claim that Galactose is absorbed quickly like glucose without a subsequent increase in insulin release.*

**Glucose:** In terms of immediate use of carbohydrate within the body, glucose (a monosaccharide) with a GI of 99±3 is the most important. Glucose can be directly absorbed by the small intestine and directly transported to the cells to be metabolized. Glucose can also be stored as glycogen (chains of glucose) within muscles and the liver, and can also be converted to fats for energy storage. During exercise, consumption of glucose allows the body to maintain an adequate supply of carbohydrate for metabolism. Glucose is often called dextrose when it is added to foods. The body eventually breaks down all sugars and carbohydrates into glucose, which is the form in which sugar enters cells to be used for energy.

**Sucrose** with a GI of 68±5 (otherwise known as table sugar) is composed of one molecule of glucose and one molecule of fructose. This is the white sugar that comes in many forms, such as powdered or granulated. It is usually made from refining extracts of sugar beets or sugar cane.

Maltodextrin a.k.a. Glucose polymers GI=99±3: 
Lactose GI=46±2  
Maltose GI=105±12  
Honey GI=55±5  
Gatorade® GI=78±13

### Timing and type of carbohydrate intake:

One must also consider the timing of consumption to be crucial to the carbohydrate’s effectiveness. Pre exercise it is very important to maximize muscle glycogen stores. Carbohydrates are most beneficial during exercise bouts greater than 30 minutes in length. Remember that more of a good thing is not always better. Too much sugar too fast will decrease absorption of fluids and carbohydrates and will cause GI distress and bloating/cramping. Properly formulated sports drinks (6% carbohydrate or 14g/8oz) are more rapidly absorbed and are more effective at replacing fluids than water, soft drinks or juice. Gatorade Sport Science recommends supplementing 30-60 grams of carbohydrates per hour of exercise (Coggan & Coyle, 1991; Murray et al., 1991). This is equivalent to 32 – 64 ounces of a 6% sports drink per hour. Consuming carbohydrates in liquid form is optimal for absorption during endurance exercise because it not only ensures rehydration but also a more consistent sugar concentration than sugars in solid form. Gels are another option and should be used consistently during exercise along with fluids to avoid the pitfalls of the blood sugar rollercoaster.

By Sally Warner MA, Ph.D.

### Why is glycemic index important?

From the corresponding graph it is clearly evident that the GI can affect your primary fuel supply quite dramatically. Consuming a high GI carbohydrate prior to a race or workout can cause your blood sugar to spike, then quickly fall below optimal levels, while a low GI carbohydrate can help stabilize your energy release. Your body’s physiological response to carbohydrates differs considerably before, during and after your workouts, making it critical to chose the
Recommendations: The depletion of carbohydrate stores within the body leads to bonking, which hinders your ability to race and/or train hard. The ability to rapidly replenish carbohydrates after training, and the ability to consume and convert ingested carbohydrates into a usable form of carbohydrate is important in allowing you to train and compete at your best. Ingestion of the wrong carbohydrates at the wrong time, or ingesting too little carbohydrate can impair performance both in the short term and long term.

Before: The most important pre exercise consideration is to make sure you have topped off your carbohydrate stores. The second thing to consider is making certain you DO NOT consume high GI foods or drinks just prior to racing. Consumption of lower GI foods 30-60 min prior to an endurance exercise bout tends to promote some positive effects during exercise including: 1) Minimizing the hypoglycemia that occurs at the start of exercise. 2) Increasing the concentration of fatty acids in the blood. 3) Increases fat oxidation and reducing reliance on carbohydrate fuel. This carbohydrate sparing prolongs your endurance and helps prevent the ‘bonk’.

During: The GI of a food consumed during exercise is probably less important than at other times because the insulin response to carbohydrate ingestion is suppressed during exercise. Much research has focused on carbohydrate drinks and foods during exercise to slow the depletion of the body’s carbohydrate stores and thus delay the onset of fatigue. Exercise-induced elevation in epinephrine depresses the release of insulin from the pancreas. Thus, concerns about carbohydrate feedings increasing insulin and depressing fatty acid availability is less likely to occur when carbohydrate is fed during exercise. The jury is still out on the ideal type of carbohydrates during exercise, though in theory since insulin is modulated and high GI carbohydrates enter the blood stream quicker, it makes sense to stick to a high GI carbohydrate. The best advise is to stick to what you are used to.

After: Following exercise your primary concern is to replenish lost glycogen stores. The ability to replenish these stores fully determines how ready you will be for the next workout. It is at this time where a high GI carbohydrate has the ability to shuttle glycogen into the cells quicker and more

notes from the Endurance Research Board

Glucose Regulation: While the availability of carbohydrate for use within the cells is extremely important, much of the regulation of glucose concentration rests not solely with the type of carbohydrates ingested, but in the hormonal regulation of glucose. Among the hormones that are especially important to glucose concentrations are insulin, glucagon, epinephrine, and cortisol. Exercise, in addition to carbohydrate type and timing of ingestion, also modulates the release of these hormones. As you can see, there is a whole lot more to carbohydrate than just simple sugars and complex carbohydrates. One of the more important tools that an athlete can use to differentiate the potential impact that a given type of carbohydrate will have on insulin release and subsequent carbohydrate uptake (especially when not exercising) is the glycemic index (GI). Foods with a higher glycemic index will be broken down into glucose faster, and will cause a greater surge in insulin release, which works to speed the transport of glucose into the cells. Foods with a lower glycemic index will more slowly be converted to glucose, and will cause a smaller release of insulin. Immediately before exercise and when resting, you should consume more foods with a lower glycemic index. During exercise, and immediately after exercise, it is better to consume foods with a higher glycemic index. Overall, many nutritionists will suggest that the GI is just splitting hairs, and that consuming adequate carbohydrate is most important. If you’ve already got the right amount, though, getting the right type can help boost your performance to the next level!

By Neal Henderson MS CSCS
efficiently than low or moderate GI carbohydrates. If you have access to a high GI carb, then grab it, if not grab any carbohydrate you can get your hands on and swallow it down with water.

References:


Glycemic Index scores: www.mendosa.com