Original Studies on Carbohydrate and Exercise Performance

Complex Carbohydrates and Athletic Performance

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Eating enough complex carbohydrate foods is also important for enhancing athletic performance. Your muscles can absorb and store carbohydrate sugars. The carbohydrates provide some of the energy for physical activity. Regularly exercised muscles can store double the amount of carbohydrate sugar, giving you more strength and endurance.

When a muscle has depleted its reserve of carbohydrate sugars during exercise, it becomes fatigued and soon reaches the point of complete exhaustion. During exercise that requires prolonged endurance (jogging, cycling, swimming), muscles extract carbohydrate sugars from the bloodstream at a rate of 30 to 40 times faster than during rest or light activity. Those sugars are drawn from the liver.

A diet rich in complex carbohydrates keeps the supply of carbohydrate sugar stored in your liver and muscles high. This supply helps prevent your blood sugar levels from falling during exercise.

In marathon running, an empty carbohydrate fuel tank is known as "hitting the wall". Sometimes, at around the 20-mile mark of a 26.2-mile (42 km.) marathon, the runners may begin to slow down, becoming weak and dizzy. Often, they can only walk the last few miles, if they can continue at all. What has happened is that the muscles have exhausted their stores of carbohydrates, and the liver can no longer maintain normal blood sugar levels. The bran and nervous system, deprived of the energy that they need to function properly, may cause so much dizziness that the runner falls. Athletes in many sports can suffer from carbohydrate depletion.

Athletes refer to the intake of a diet rich in complex carbohydrate foods as carbo-loading. By getting regular exercise and eating sufficient carbohydrates you can expand your liver and muscle carbohydrate stores daily to provide you with a winning edge in your athletic pursuits. Carbo-loading will enhance both your endurance fitness level and your muscular strength.

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Enhancing Exercise Performance With Pre-Game Carbohydrate Intake

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Carbohydrates are an important source of energy for sports that involve repeated bouts of explosive power and for long distance events. As this defines most sports, carbohydrate intake is a critical determinant in optimizing athletic performance. A short list of sports that rely on carbohydrate as a predominant energy source include (basketball, soccer, hockey, la crosse, football, tennis, squash, badminton , racquetball, handball, middle and long distance running, swimming, rowing, and cross-country skiing).

For sports of this nature adequate carbohydrate intake before, during and after exercise is associated with enhanced exercise performance. Thus, knowing the right amount, type and timing of carbohydrate helps to provide an athlete with a competitive edge.
The early studies on carbohydrate and exercise performance date back to the late 1960s (Bergstrom et al., 1967), which confirmed the work of Christensen and Hansen, who 30 years earlier had demonstrated the importance of increased dietary carbohydrate for endurance exercise performance. So, at a time when professional athletes were still eating a pre-game steak, research was already in place to suggest that any combination of pasta, rice, bread, vegetables, fruits, peas and beans would have been a better choice to enhance performance.

Recent studies have proven that an athlete's diet should consist of 60-70% carbohydrate calories during heavy training where carbohydrates are a predominant energy source.

The pre-exercise or pre-game meal should consists primarily of carbohydrates and be ingested 3 to 4 hours prior to competition. This should not include a lot of refined sugar products, but rather carbohydrates that don't abruptly cause a rise in blood sugar or insulin concentrations. Good examples include oatmeal, whole wheat bread, whole wheat pasta with tomato sauce , brown rice, most vegetables, most fruits, peas, beans, high fiber breakfast cereals (low in sugar) with low fat milk or yogurt (non fat or 1% milk fat).

The pre-exercise or pre-game carbohydrate meal is intended to expand the liver's carbohydrate reserves, which become the exclusive source of blood sugar during the sport or training session. During exercise the muscles at work extract sugar (carbohydrate) from the bloodstream at rate that is 30-40 times greater than under resting conditions. Thus, to prevent liver carbohydrate depletion and a fall in blood sugar adequate carbohydrate intake 3-4 hours prior to the event is an essential part of optimal sports nutrition. In addition, it is possible that a portion of these carbohydrates can contribute to reloading of the muscles' carbohydrate fuel tank, which is a critical factor in for sports performance as we will discuss.

In one study Sherman et al. demonstrated that ingestion of 312 grams (1,248 calories) of carbohydrate 4 hours prior to strenuous exercise resulted in a 15% improvement in exercise performance. As a side note, no improvement was observed when either 45 grams

(180 calories) or 156 grams (624 calories)of carbohydrate was ingested. Therefore the meal must contain a sufficient total number of carbohydrate calories to yield a sports-enhancing effect when strenuous or prolonged exercise is involved.

In contrast to this, carbohydrate ingestion 30 to 60 minutes prior to strenuous exercise has been shown to impair exercise performance. This is believed to be due to the effects of insulin which produce a rapid drop in blood sugar when combined with exercise. Thus, it is undesirable to raise blood insulin levels just prior to strenuous exercise.

For this reason drinking or eating carbohydrates just prior to exercise can be detrimental to performance. The one exception to this rule is fructose sugar. Fructose sugar does not disrupt blood sugar or insulin levels to a significant degree and its ingestion 30 minutes prior to exercise has been shown to enhance exercise performance. For this reason I often suggest to athletes that they ingest up to 20 grams of fructose sugar added to cold water (20-25 ounces) 30 minutes prior to their event. This recommendation is less important for more moderate exercise activities such as recreational walking or for submaximal exercise lasting less than one hour. The general importance of carbohydrates for strenuous or long distance events is that it provides a high octane type of fuel that enables muscles to work at a higher rate of power output. During exercise if muscle carbohydrate stores become depleted, muscle power will suffer. Hence, the athlete slows their pace during long distance events or is unable to achieve or maintain their optimal speed in sports that require repeated bouts of rapid acceleration and sprints.

Prior to exercises of this nature refueling of the liver carbohydrate and muscle carbohydrate fuel tank (glycogen reserves) is crucial to performance capabilities.

Knowing how to replenish carbohydrates during exercise, post exercise and during day to day meal planning is also essential and is discussed in other articles in this program.

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Essentials Of Carbohydrate Replenishment After Exercise

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As reviewed in other articles on this site, carbohydrate nutrition is an important determinant of exercise performance for sports that require repeated bouts of all-out-effort (i.e. hockey shift) and long-distance races. Consuming a carbohydrate-rich meal 3-4 hours prior to exercise, a fructose-rich drink 30 minutes prior to exercise and the ingestion of 5-8 ounces of a carbohydrate sports drink every 10-15 minutes during exercise are considered prudent ergogenic (exercise enhancing) strategies in the field of sports nutrition. This applies primarily to sports activities executed at a strenuous level and lasting a minimum of 60-90 minutes.

Once the training session or sports event is over there are two concerns to address with respect to carbohydrate replenishment. First, the craving within the muscle for carbohydrate storage is extremely high in the first 2 to 6 hours following the completion of exercise. Thus, this represents an ideal opportunity to rapidly drive carbohydrates into the muscles' carbohydrate fuel tank (glycogen) thereby helping to prepare the muscle for the next training session or competition.

Secondly, on a more long-term basis it is important to derive sufficient carbohydrate calories from day to day as it requires at least 24 hours to fully refuel the muscles' carbohydrate fuel tank. Very conveniently the size of the muscles' carbohydrate fuel tank doubles with exercise training. So, the key is to completely refuel the tank between training sessions as greater concentrations of muscle glycogen are correlated with better performance. This includes improved ability to perform repeated all-out-sprints, better sustained maximum power in long distance events and the postponement of fatigue. Hence, reloading the muscles' carbohydrate stores to a maximum level is deemed to be very desirable for athletes competing in a wide variety of sports. The ability to store twice as much carbohydrate in trained muscles versus untrained muscles is known as glycogen super compensation, which requires sufficient daily carbohydrate intake. For sports that rely heavily upon carbohydrate energy the athlete's diet should consist of 60-70 percent carbohydrates from day to day.

On a more technical level the rate of post-exercise muscle glycogen storage, when supplied by dietary carbohydrates is reported to be 5 to 8 mmol/kg/hour, which means at least 20 to 24 hours are required for complete restoration of normal muscle glycogen levels. The rate of resynthesis is faster if carbohydrates are consumed immediately following exercise rather than delaying carbohydrate intake by 2 hours. Thus, athletes should ingest carbohydrates as soon after exercise as possible.
Interestingly, in the early post-exercise period the optimal carbohydrate intake appears to be 50 grams every 2 hours aiming for a total carbohydrate intake in 24 hours of 600 grams (2,400 calories) for athletes involved in strenuous training or tournament weekends where carbohydrate demanding sports are involved (i.e. basketball, hockey, swim meets).

Ingestion of simple rather than complex carbohydrates are preferred between games and events scheduled on the same day. Examples include sports drinks, sports bars, pancakes, bread, rice, pasta, potatoes, fruit and fruit juice. Sweet vegetable such as carrots, squash and sweet potatoes are also a consideration. If the next game or race is less than 3 hours following the preceding one, then a complete meal is not recommended. Rather, reliance upon sports drinks, sports bars, fruit juice, fruit and carrot sticks are viable dietary suggestions.

In the event of over training that produces muscle soreness, muscle damage and presence of inflammatory cells, the refueling of muscle carbohydrate (glycogen resynthesis) is reduced, resulting in poorer performance in future events. The effect of muscle damage can be partially overcome by the ingestion of increased amounts of carbohydrate. Thus, athletes should be aware of the potential need of increased dietary carbohydrate following intense, prolonged exercise that produces muscle damage and soreness.

From a metabolic standpoint glucose and sucrose (white sugar) result in faster muscle glycogen resynthesis than fructose, although fructose may be of more benefit in the restoration of liver glycogen.

In summary, in view of the importance of carbohydrate for performance in many sports, the goal of carbohydrate nutrition strategies aimed at before, during and after exercise as well as day to day carbohydrate loading can help to optimize athletic performance, providing an important competitive edge.

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Essentials of Carbohydrate Replenishment During Exercise

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As I've described in a previous article on this site, 60-70 percent of an athlete's diet should be comprised of carbohydrate calories where the sport involves repeated bouts of all-out effort and for long distance events. For these events, carbohydrate energy represents the predominant energy source for maximum sustained power. Carbohydrate depletion during these events is known to hasten the onset of fatigue and to hinder performance capabilities. As a result athletes should be aware of effective carbohydrate repletion techniques as a means of optimizing their performance. Prior to exercise a carbohydrate rich meal should be consumed 3-4 hours before the game or training session. Thirty minutes prior to exercise 10-20 grams of fructose sugar mixed with 20-25 ounces of water can also maximize carbohydrate availability and utilization, enhancing performance.

Consuming carbohydrates during prolonged exercise events has also been shown to improve performance. Numerous studies have demonstrated increased exercise time to fatigue, power output during exercise and improved sprint performance following prolonged exercise when carbohydrate is ingested during exercise. Carbohydrates ingested during intensive or prolonged exercise are able to maintain blood sugar more effectively, thereby providing an immediate source of carbohydrate energy to the exercising muscle. As a result this strategy spares the rapid breakdown of liver carbohydrate, which is then able to provide blood sugar for a longer period of time during the event. Indeed, a recent report has observed a 59% reduction in liver carbohydrate (glucose) production during prolonged exercise when carbohydrate is ingested. This strategy enables the liver to deliver carbohydrate through the bloodstream as blood sugar, thus the exercising muscle uses up its own carbohydrate stores (glycogen) at a slower rate. Slowing the depletion rate of muscle carbohydrate stores allows the muscle to work at higher levels of power for a longer period of time; hence performance improves.

During prolonged exercise the muscle breaks down carbohydrates as a source of energy at a rate of 1-1.5 grams per minute. Based on a number of studies it appears that athletes need to ingest carbohydrates at a rate that will supply them with carbohydrates at approximately 1 gram per minute. This can be achieved by the ingestion of 600 to 1,000 ml/hour of solutions (drinks) containing 6-10% carbohydrate. This simply means that for every 100 ml of water in a sports drink there should be no more than 6-10 grams of carbohydrate. Any more carbohydrate than this will slow down the rate of gastric emptying and water absorption into the bloodstream. Gastric emptying means the rate at which carbohydrates and fluids pass through the stomach into the small intestine where the maximum amount of absorption into the bloodstream occurs.

Soft drinks, for instance, contain at least 12 grams of carbohydrate per 100 ml of water and, therefore, are not good sports enhancement beverages.

The popular carbohydrate sports enhancement drinks in the marketplace all meet the 6-10% carbohydrate criteria as I have explained it.

As for the type of carbohydrate that is best to include in a sports enhancement drink during competition, there is little difference between maltodextrins (glucose polymers) glucose and sucrose in their metabolic and performance effects during exercise. However, maltodextrin solutions tend to be less sweet, and therefore more palatable, than solutions of only simple sugars. In contrast, fructose ingestion during prolonged exercise does not improve performance. Fructose is the beverage of choice 30 minutes prior to exercise, but not during exercise.

As a general guide as to how to practically apply this information, let me summarize this information in the following way. During a strenuous exercise event that will last for more than 60 minutes, consider drinking 5-8 ounces of a carbohydrate based sports enhancement drink every 10-15 minutes. This will not only provide the right concentration and type of carbohydrates to stave off carbohydrate depletion in your liver, bloodstream and exercising muscles, but also provides an optimal strategy to prevent dehydration. Most of these drinks (i.e. Gatorade) also provide sufficient sodium and/or potassium to prevent hyponatremia which is a loss of sufficient sodium (from sweating) to result in a life-treatening conditioning involving brain swelling and other complications. As a rule usually a minimum of 3 to 4 hours of continuous sweating is required to develop hyponatremia, but it remains a nutritional concern for certain types of sporting events.

In conclusion the use of carbohydrate sports drinks is a proven method to enhance athletic performance in events lasting at least 60-90 minutes, which require repeated bouts of explosive power and in long distance events where maintaining optimal speed is critical to the outcome. Consuming 5-8 ounces of these drinks every 10-15 minutes is the best way to deliver the optimal amount of carbohydrate to the exercising muscle during intense and prolonged activity. As well, colder fluids are absorbed faster than fluids at room temperature. Thus, colder beverages are a better choice for optimal carbohydrate and fluid replenishment.

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