Glycogen Replenishment After Exhaustive Exercise

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Throughout the centuries, dietary intake has been a source of concern to athletes in search of an ergogenic edge over opponents.

It wasn't until 1866 that it was demonstrated that there was insignificant, if any use of protein as a fuel during exercise. Since that time, innumerable studies have refuted the notion that a high protein intake will enhance athletic performance.

Since the conclusion of the Kraus-Weber Tests in the 1950s, there has been ever- increasing awareness and concern for cardiopulmonary fitness and health in Americans. Endurance type activities such as Nordic skiing, cycling, running, triathalons, and swimming have become in vogue, and as a result, more intense attention has been devoted to dietary manipulations which may provide an ergogenic effect, thus prolonging time to exhaustion, or delaying the onset of blood lactate accumulation (OBLA) in an attempt to compete at a higher intensity, longer.

The classic study by Christensen and Hansen in 1939 established the effect of a high carbohydrate diet upon endurance time, and that pre-exercise glycogen levels exerted an influence in time to exhaustion. Subsequently, it was discovered that if an athlete, after depleting glycogen reserves, consumed a high carbohydrate diet for two to three days prior to an athletic event, there would in fact be higher glycogen levels than prior to exercise. This "supercompensation" effect became the basis for carbohydrate loading undertaken by endurance athletes.

Therefore, the concentration of muscle and liver glycogen prior to exercise plays an important role in endurance exercise capacity. In exhaustive exercise many studies have observed significant depletion of both liver and muscle glycogen. It is interesting to recognize that the point of exhaustion seems to occur upon the depletion of liver glycogen. Conversely, muscle glycogen reserves, though significantly lower are only 65-85% depleted, versus the 85-95%

depletion exhibited for liver glycogen. This should make it readily apparent that liver glycogen is an integral determining factor in an athlete's time to exhaustion. It follows that endurance athletes who maintain a daily regimen of endurance training without glycogen repletion may severely deplete their glycogen reserves.

Glycogen, the major reservoir of carbohydrate in the body, is comprised of long chain polymers of glucose molecules. The body stores approximately 450-550 grams of glycogen within the muscle and liver for use during exercise. At higher exercise intensities, glycogen becomes the main fuel utilized. Depletion of liver glycogen has the consequence of diminishing liver glucose output, and blood glucose concentrations accordingly. Because glucose is the fundamental energy source for the nervous system, a substantial decline in blood glucose results in volitional exhaustion, due to glucose deficiency to the brain. It appears that the evidence presented in the literature universally supports the concept that the greater the depletion of skeletal muscle glycogen, then the stronger the stimulus to replenish stores upon the cessation of exercise, provided adequate carbohydrate is supplied.

Though most of the evidence presented on glycogen is related to prolonged aerobic exercise, there is evidence that exercise mode may play a role in glycogen replenishment, with eccentric exercise exhibiting significantly longer recovery periods, up to four days post-exercise. Muscle fiber type is another factor implicated in the replenishment of glycogen in athletes, due to the enzymatic capacity of the muscle fiber, with red fiber appearing to be subjected to a greater depletion, but also undergoing repletion at a significantly grater rate.

Though early literature appeared to indicate that the time course of glycogen replenishment after exercise-induced depletion was 48 hours or more, more recent data have controverted this thought. One study reported that a carbohydrate intake totaling up to 550-625 grams per day was found to restore muscle glycogen stores to pre-exercise levels within the 22 hours between exercise sessions. The findings of this study were supported by second study in which a carbohydrate intake of 3100 kcal resulted in complete resynthesis of glycogen within 24 hours.

There also appears to be a two-hour optimal window immediately after the cessation of exercise for the administration of carbohydrates. Simple carbohydrates appear to be the preferred replacement during this replenishment period.

Normally, 2% of glycogen is resynthesized per hour after the initial 2 hours immediately after exercise. With administration of 50 grams of carbohydrate every 2 hours, the rate rose to 5% per hour, but did not rise when additional carbohydrate was administered. Administration of .7grams per kg body weight every two hours is another strategy that appears to maximize the rate of glycogen resynthesis. There is also some evidence that even smaller loads (28 grams every 15 minutes) may induce even greater repletion rates.

Therefore, at least 20 hours are required to recover muscle glycogen stores, even when the diet is optimal. So, athletes working out two times per day should complete one workout at a diminished workload to relieve the reliance on glycogen reserves.

The principle of glycogen resynthesis and supercompensation has great practical implications, not only in athletics, but also within industry for workers who consistently undergo depletion of glycogen stores due to prolonged bouts of exertion, or extended lifting tasks which would be glycolytic in nature; due to the duration, and also the myofibrillar ischemia induced by static contractions.