By Todd Astorino, MS, and Len Kravitz, PhD

Glycogen and Resistance Training

The role of glycogen (stored carbohydrate in muscle) in aerobic exercise has been associated with increased work output and duration (Haff et al. 1999). Carbohydrate is the body's preferred substrate during endurance exercise, due to its efficient energy yield per liter of oxygen consumed. Previous resistance training research suggests that weight training is associated with a consequential depletion of muscle glycogen stores. Robergs et al. (1991), for example, demonstrated that subjects performing six sets of leg extensions at 35 and 70 percent of one repetition maximum (1 RM) resulted in a decrease of muscle glycogen by 38 and 39 percent, respectively.

This article will review two recent studies that further elucidate the role of glycogen in resistance exercise. After reviewing the studies, personal trainers hopefully will have a better understanding regarding the appropriateness of carbohydrate replenishment recommendations for clients engaged in resistance exercise programs.

Energy for Resistance Exercise

Due to the intense and short-term nature of individual bouts of resistance training, it seems likely that this activity would be highly dependent on muscle glycogen for ATP (adenosine triphosphate) provision. High-intensity exercise of short duration (up to 30 seconds) is characterized by a rapid breakdown of phosphocreatine for the production and use of ATP, as well as stimulation of glycogenolysis (breakdown of glycogen) and glycolysis (breakdown of glucose), with a lesser contribution of oxidative metabolism.

In a study by Tesch, Colliander & Kaiser (1986), nine bodybuilders completed five sets each of front squats, back squats, leg presses and leg extensions to fatigue, comprising 30 minutes of exercise. Biopsies of muscle samples were obtained from their vastus lateralis before and immediately after exercise. Muscle glycogen concentration was 26 percent lower postexercise—a rather modest decline considering the demanding exercise protocol completed. This outcome led the authors to conclude that energy sources, in addition to muscle glycogen, support heavy resistance training.

Data from Essen-Gustavsson & Tesch (1990) focusing on nine bodybuilders performing the same exercise regimen as in the study above, revealed a 28 percent decrement in muscle glycogen content, as well as a 30 percent decrease in muscle triglyceride content. This finding suggests that intramuscular lipolysis (breakdown of triglycerides) may also play a role in energy production during repeated high-intensity exercise.

Overall, research suggests that intramuscular glycogen is an important fuel supporting weight training exercise, but not the only substrate.

Study One: Carbohydrate Restriction Impact

Study: Leveritt, M., & Abernethy, P. J. 1999. Effects of carbohydrate restriction on strength performance. *Journal of Strength and Conditioning Research, 13* (1), 52-7.

Purpose: To determine whether depleted muscle glycogen stores in conjunction with aerobic exercise compromises strength performance.

Methods: Subjects were five men and one woman (mean age 20.3 ± 2.3 years) who performed resistance exercise under a control (CON) condition (no strenuous exercise for at least 48 hours prior to testing) and after a carbohydrate-restricted program (EXP). The EXP condition included 60 minutes of submaximal cycling and four 1-minute bouts of maximal exercise, followed by 48 hours of reduced carbohydrate intake. The resistance exercise consisted of three sets of squats (80% 1 RM) and five sets of isokinetic knee extensions, all at different contractile speeds.

Results: In comparing the CON to the EXP testing condition, the most observable difference was noted in squat performance, with no significant differences in the knee extension trials. There was a decrease in the average total number of repetitions in set one (CON = 18 reps versus EXP = 12 reps) and set two (CON = 13.5 reps versus EXP = 10.33 reps). However, there was no difference between the CON and the EXP groups at any of the five contractile speeds of isokinetic knee extensions.

Explaining differing outcomes of squat sets versus knee extensions sets (to an aerobic and carbohydrate-restricted program), the authors

FASTING AND FAT BURNING

"To burn more fat, should I avoid eating prior to my morning workout?" Personal trainers often hear that question from their clients, and the answer should be "no."

The body loses up to 80 percent of its muscle glycogen stores during sleep. This stored form of carbohydrate is imperative for completing a demanding muscular fitness workout. With adequate carbohydrates prior to working out, clients have more energy to realize an increase in muscle strength and size, greater caloric expenditure and enhanced metabolic rate. A light breakfast will also spare the protein that muscles need.

Following are some eating suggestions for clients before a morning workout:

- a bowl of oatmeal with skim milk
- an egg substitute and toast
- an English muffin with peanut butter
- a liquid supplement containing carbohydrate and protein (if gastrointestinal distress is a concern)

—Jenna A. Bell, RD, LD

summarized previous research depicting substrate utilization differences in the exercise type. Isometric exercise is impaired by reducing glycogen content; no change has been seen in the isokinetic exercise. The authors hypothesized that differences in the present study were also due to the exercise type. Isokinetic exercise bouts consisted of relatively short duration (1.5 to 7.5 seconds) versus sets of squats (about 30 seconds per set). It was believed that energy production of the isokinetic exercise was due to the breakdown of creatine phosphate, while the utilization of glycogen was more apparent in the longer-lasting squat exercise regime.

Study Two: Carbohydrate Supplementation Impact

Study: Haff, G. G., et al. 1999. The effect of carbohydrate supplementation on multiple sessions and bouts of resistance exercise. *Journal of Strength and Conditioning Research, 13* (2), 111-17.

Purpose: To examine the effects of carbohydrate supplementation on multiple sets of resistance training exercise during the second training session on a given workout day. For athletes completing multiple high-intensity strength training sessions per day, maintenance of muscle glycogen stores is critical.

Methods: Six resistance-trained men (mean age 24.3 ± 2.1 years) ingested a 250-gram carbohydrate supplement or placebo during a morning training session, rested for four hours, and then performed a second session consisting of multiple sets of light-intensity squats (55% 1 RM) to exhaustion.

Results: During the second session, the number of sets and repetitions performed was higher with the carbohydrate consumption and subjects were able to exercise for 30 minutes longer. The authors concluded that athletes engaging in multiple exercise sessions per day (ranging from mild to high intensity) will receive a performance advantage with carbohydrate ingestion, via maintenance of intramuscular glycogen stores, due to greater glycogen resynthesis during recovery. In addition, the carbohydrate supplementation not only increased workout performance, it markedly increased workout duration.

Practical Applications

For the recreational athlete participating in weight training, muscle glycogen stores are best maintained with a well-balanced and calorically-sufficient diet. Personal trainers must consider exercise habits and goals of weight-training clients before prescribing carbohydrate supplementation to benefit exercise performance. Trainers should remind clients that excess carbohydrate intake (exceeding bodily energy expenditure needs) will result in weight gain. However, it is apparent from the two studies reviewed that individuals performing concurrent aerobic exercise with high-intensity resistance training and/or completing multiple training sessions per day should be concerned with maintenance of glycogen stores, since glycogen depletion may reduce work output and duration.

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ADDITIONAL REFERENCES

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