

Chapter IV Summary

Seeking to improve appearance and performance many athletes often experiment with dietary supplements. Many of these supplements advertise performance claims that are not documented in current research (Grunewald and Bailey, 1993). This may result in athletes spending money on products that are of no benefit. Out of 309 body builders surveyed, 59% spent \$25 to \$100 a month on supplements (Brill and Keane, 1994). Thirty-one percent reported using carbohydrate loading beverages at least once a week.

Numerous studies have shown that carbohydrate supplementation improves aerobic exercise performance. Mechanisms suggested to explain the ergogenic effect of carbohydrate include maintenance of blood glucose permitting high rates of carbohydrate oxidation (Coggan and Coyle 1991) and muscle glycogen sparing (Hargreaves et al. 1984). Ingesting carbohydrate prior to resistance exercise may increase blood glucose availability and improve performance if muscle glycogen becomes limiting.

Carbohydrate supplementation is also associated with lower cortisol (Anderson et al. 1991, Deuster et al. 1992, Mitchell et al. 1990) and creatine kinase levels (Cade et al. 1991) after exercise. This may especially benefit athletes who are undergoing energy restriction, since fasting (Beer et al. 1989, Comeron et al. 1991, Veldhuis et al. 1993, Bergendahl et al. 1996) and resistance exercise have been shown to increase cortisol levels (Kraemer et al. 1987, Kraemer et al. 1993, McMillian et al. 1993).

The studies examining the effect of carbohydrate supplementation on resistance exercise performance have reported conflicting results. Lambert et al. (1991) reported a trend toward improved performance when a glucose polymer solution was ingested prior to multiply bouts of leg extension exercises. Other studies have reported no effect of carbohydrate supplementation on resistance performance (Vincet et al. 1993, Conley et al. 1995). The current study was designed to evaluate if carbohydrate ingestion prior to resistance exercise improved performance, lowered cortisol and CK levels, and decreased Rates of Perceived Exertion.

Initially, we wanted subjects to perform sets of leg extensions for an hour. The leg extension machine only has 200 pounds of resistance on it so it was not possible to do a 10RM for both legs. It was then decided that the subjects would only use one leg during the performance test. We wanted the workout to be similar to actual workouts so we added squats, bench press, and leg press. Since there is more risk of injury with a 1 RM test, the primary investigator could not adequately spot the subjects during the squats, and the leg extension machine did not have enough resistance to determine a 1RM for most subjects, it was decided to do a 10RM strength test. Five male subjects completed the pilot study. All of them were currently performing resistance exercises on a regular basis. 10RMs were determined for squats, bench press, leg press, and one-legged leg extensions. They did the performance test twice to determine reliability. The performance test consisted of 5 sets of squats, bench press, leg press, and one-legged leg extensions at 80%, 80%, 70%, 60% and 60% of 10RM. The dependent measure was the number of

repetitions performed during the 6th set of one-legged leg extensions at 80% of 10RM. The first two subjects rested 2.5 minutes between sets, the last 3 subjects rested 2 minutes between sets. The estimate of reliability (Spearman Rho) between Trial 1 and Trial 2 was .99 which is significant at the .01 level. After this pilot test it was decided to also use bench press as a performance measure and for the 5th set of leg extension and bench press to be performed at 80% of 10RM. Bench press repetitions to failure were added to provide a parameter for measuring upper body performance and resistance exercise performance during the middle of the workout.

Twenty-two male resistance trainers participated in this study. Sixteen subjects were randomly assigned to either a carbohydrate (C, n=8) or placebo (P, n=8) group. The remaining six subjects served as a control group (N) to control for the possible effects of repeated testing on the resistance training performance. The control subjects only participated in the workout and performance testing sessions. They did not undergo energy restriction or blood draws.

Subjects in the experimental groups completed diet records during the first three days of the study. These diet records were analyzed using Nutrition IV and modified to provide an exchange diet that supplied 60% carbohydrate, 15% protein, and 25% fat. The exchange diets were consumed on the days of blood draws, Days 7 and 11.

The experimental subjects underwent three days of energy restriction (Days 8-10). They consumed a formula diet that supplied 18 kcal kg⁻¹ d⁻¹ consisting of 54.7% carbohydrate, 21.3% protein, and 25% fat (Ensure, Ross Laboratories). Body weight was assessed daily to ensure compliance.

All subjects underwent strength tests the week before beginning the study. A 10 repetition maximum (10RM) was determined for parallel squats, bench press, leg press, and one-legged leg extension. The strength test was done twice with two days of recovery between tests. The resistance workout was based on the 10RM measurements. Subjects performed five sets of each exercise. The resistance for each exercise was 80%, 80%, 70%, 60%, and 60% of 10RM. The subjects were asked to rest two minutes between each set. The resistance workout was done on Days 1, 3, and 9. On Days 5, 7, and 11 subjects did resistance exercise performance tests (Trials 1, 2, and 3). These were identical to the standardized workouts except the final sets of bench press and leg extension were done to exhaustion at 80% of 10RM.

For Trials 2 and 3, (Days 7 and 11) experimental subjects had blood drawn 30 minutes before, 10 minutes post, 6 hours post, and 24 hours post exercise. The blood samples were analyzed for cortisol, creatine kinase, and glucose.

On Day 11, experimental subjects had blood drawn and then consumed either a carbohydrate (1g kg⁻¹) or placebo beverage thirty minutes prior to exercise. The placebo beverage was sweetened with NutraSweet. It was the same volume as the carbohydrate beverage and was similar in color. Subjects were blind to which beverage they received.

Both experimental groups lost a significant amount of body weight due to energy restriction. The subjects lost an average of 2.24 ± 0.2 kg. There was not a difference between groups in weight reduction.

Resistance exercise performance was not enhanced by carbohydrate supplementation or energy restriction. When performance was measured as the number of repetitions performed during the final set of bench press, there was a significant group*time interaction. While C significantly decreased the number of repetitions performed for Trial 2 versus Trial 3 (17.6 ± 0.7 to 17.3 ± 1.0), P and N improved (15.0 ± 1.4 to 17.3 ± 0.8 for P, 15.0 ± 2.7 to 16.7 ± 2.3 for N). N experienced a significant improvement, but the improvement for P was not significant. It should be noted that C performed more repetitions during Trial 2 than the other two groups, but this was not significantly different. The interaction between groups and time is due more to the improvement for P and N than for the small decrease in C. Performance as measured as the number repetitions performed during the final set of leg extension showed no significant interactions between time and groups.

The subjects who received a carbohydrate beverage prior to resistance exercise experienced a significant decrease in performance when performance was measured as the number of bench press repetitions done to failure. These results should be interpreted with caution. This decrease was small, less than one repetitions. Such a small decrease in performance probably does not have any practical application. The placebo group non significantly improved and the control group significantly improved the number of bench press repetitions on Trial 3. These groups performed fewer repetitions on Trial 2 than the carbohydrate group. When performance was measured at the end of the workout as the number of repetitions performed to failure during leg extension exercises, there was no group*time interaction.

RPE was not affected by carbohydrate supplementation. There was a significant trial effect for RPE after the 5th sets of squats, bench press, and leg extension. However, this cannot be attributed to energy restriction since there was no significant difference between the experimental groups and the control group. During Trial 3, subjects reported lower RPE values at the beginning of the workout as compared to Trial 2, but by the end of the workout they reported higher RPE values. When the groups were collapsed, RPE was significantly lower after the 5th set of parallel squats during Trial 3 compared to Trial 2 (11.1 ± 0.54 for Trial 2 versus 9.7 ± 0.51 for Trial 3). RPE was significantly higher during Trial 3 compared to during Trial 2 after the 5th set of leg press (11.0 ± 0.4 during Trial 2 versus 12.2 ± 0.6 during Trial 3) and the 5th set of leg extension (16.4 ± 0.3 during Trail 2 versus 17.0 ± 0.4 during Trial 3).

Serum glucose, cortisol, and CK levels were not affected by carbohydrate supplementation. Glucose tended to be non-significantly lower on the day of Trial 3 as compared to the day of Trial 2 when both groups were collapsed ($p=0.6$). Serum glucose levels were non significantly higher after exercise during Trial 2 and non significantly

lower after exercise during Trial 3. The decrease in serum glucose following Trial 3, may be due to an increase in glucose uptake by the muscle or liver after three days of energy restriction. If muscle glycogen levels were lower at the start of Trial 3, more blood glucose may have been used to provide substrate for glycolysis.

Cortisol levels were not affected by carbohydrate supplementation. There was a difference in cortisol levels on day of Trial 2 compared to the day of Trial 3 when groups were collapsed. A post hoc analysis revealed that only the resting cortisol levels were significantly different. When the data for both groups were collapsed resting cortisol levels increased from 252.1 nmol/L \pm 12.0 before Trial 2 to 306.5 nmol/L \pm 17.0 before Trial 3. The decrease in cortisol 10 minutes and 6 hours post exercise that occurred for both groups is probably due to a diurnal variation since cortisol levels are typically higher in the morning than in the afternoon. Since there was not a non-exercising control group for comparison, it is not know if cortisol levels would have decreased more during the day if the subjects had not performed the resistance exercise.

Serum CK levels were not affected by carbohydrate supplementation or energy restriction. CK levels were significantly elevated at all time points after exercise as compared to resting levels. During Trial 2, CK was elevated 16% 10 minutes after exercise and 54% 6 and 24 hours post exercise relative to the pre-exercise concentration. During Trial 3, CK was elevated 29% 10 minutes post, 36% 6 hours post, and 47% 24 hours post exercise.

Research Implications

Carbohydrate beverages are often marketed for improving resistance exercise performance. Results of this study and others (Conley et al. 1995, Vincent et al. 1993) show no effect of carbohydrate supplementation on resistance exercise performance. Lambert et al. (1991) reported a non-significant trend for improved performance due to ingesting a glucose polymer solution prior to exercise ($p=0.067$ for then number of sets and $p=0.056$ for the number of repetitions). Conley and Stone (1995) hypothesized that 35 minutes of exercise during the Conley et al. (1995) study was not long enough for carbohydrate availability to become a limiting factor, but in the 56 minutes of the Lambert et al. (1991) study it did become limiting. Thus, the reason why a trend towards improved performance was reported. The 50 minutes of the current study did not produce changes in performance due to carbohydrate supplementation. Therefore, it seems unlikely that athletes who perform less than one hour of resistance training would benefit from ingesting a carbohydrate beverage prior to their workouts.

Additionally, cortisol and CK levels were not affected by carbohydrate supplementation. The lack of cortisol response to resistance exercise in the current study may be due to lower intensity (80, 70, and 60% of 10RM) or longer rest intervals (2 minutes). Research has been consistent in showing that longer rest periods prevent in cortisol levels following exercise (Guezennec et al. 1986, Nieman et al. 1995). Studies that have used rest periods of 1 minute reported significant increases in cortisol levels (Kraemer et al. 1987, Kraemer et al. 1993). Athletes who rest for two minutes or longer may not experience increases in cortisol levels due to resistance exercise.

Three days of energy restriction did significantly increase resting cortisol levels. This may negatively impact resistance trainers who are trying to increase muscle mass and strength since elevated cortisol levels decrease protein synthesis and increase protein catabolism. Therefore, it is recommended that athletes not undergo severe energy restriction.

Future Research

Carbohydrate supplementation may improve resistance exercise performance if the workout last more than one hour and the intensity of the workout is high. For this study, the intensity was kept lower because it was feared that all subjects would not be able to complete a higher intensity protocol after three days of energy restriction. For sets that utilized 60% of 10RM, most of the subjects gave RPE values that ranged from “very light” to “fairly light”. Subjects may not have been working hard enough to elicit decreases in muscle glycogen. Future studies should increase the intensity and the number of sets performed.

Additionally, the protocol was not intense enough to evoke an increase in cortisol. Future studies that want to examine cortisol response to resistance exercise should use a protocol that involves high intensity with long force production and short rest periods.

Some subjects exhibited a learning effect throughout the study (i.e. the number of repetitions performed to exhaustion increased every trial). This may be attributed to the fact that these subjects were not doing leg extension exercises during their regular workouts. All subjects had been resistance training for at least one year prior to the start of the study, but their workout routines varied. Some subjects had never done squats before and had to be instructed on proper lifting technique and allowed to practice before doing the strength test. It would be beneficial to do a study that involved subjects who were very familiar with the lifting protocol. Due the limited number of males who were willing to participate in studies involving standardized workouts, energy restriction, and blood draws, the number of potential subjects was limited. Additionally, due to time restrictions and interest of the subjects a longer maintenance period was not possible.

An additional way of improving the reliability of the performance test may relate to the initial strength test. Testing for a 1RM rather than 10RM would give a more accurate and reliable measure of strength and therefore the weight used for the performance test may produce a more reliable test. If the strength test was done more than twice prior to the first dependent measure test it may also improve the reliability. Many of the subjects in the current study were unfamiliar with doing a 10RM. Two days of testing may not have been enough to familiarize the subjects with doing a 10RM.

It was hypothesized that subjects would have lower muscle glycogen levels after three days of energy restriction and that some muscle glycogen may be synthesized after consumption of a carbohydrate beverage and before the start of the exercise bout. This could not be confirmed without taking muscle biopsies. Future studies that examine the effects of a hypoenergy diet on resistance exercise performance should use muscle biopsies

to examine the effects on muscle glycogen levels.

It would be beneficial to see if the carbohydrate beverage ingested by the subjects caused an increase in blood glucose at the start of the resistance exercise and during exercise. Future research should take a baseline sample, give the beverages, and take samples immediately before the start of exercise, during exercise, and after exercise. This would give a better idea of what is happening with blood glucose levels. This was not done in the current study due to the limited amount of funding for the study and the restricted availability of the blood technician.

In conclusion there is room for future study of carbohydrate supplementation for resistance trainers in a negative energy balance. Future research needs to examine the effects of supplementation on workouts that more closely resemble what an athlete is doing in the weight room before any broad conclusions can be drawn about carbohydrate supplementation