

Chapter III

JOURNAL MANUSCRIPT

Carbohydrate Supplementation and Resistance Exercise Performance in Males  
Undergoing Energy Restriction

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Athletes frequently reduce their caloric intake to lower their body weight. Wrestlers need to make a weight class, runners want to reduce the energy cost of exercise, and body builders are interested in appearance and reducing subcutaneous fat. This reduction in caloric intake may negatively influence resistance exercise performance. When a group of body builders decreased their body weight by 7.3 kg over 12 weeks, maximal isometric dead-lift force decreased significantly (3).

Our laboratory has shown that short-term energy restriction can result in significant reductions in muscle endurance of resistance trainers (34) and in intermittent anaerobic performance in wrestlers (35). This decrease in anaerobic performance may be associated with a decrease in muscle glycogen after energy restriction.. It is possible that a reduction in muscle glycogen that could occur with energy restriction may mediate impaired performance because resistance exercise uses muscle glycogen as a fuel (23,30).

Blood cortisol levels may be higher in athletes undergoing energy restriction. Significant increases in cortisol levels have been reported in fasting subjects (3, 4, 8, 32). Resistance exercise has also been reported to increase cortisol levels (20, 21, 25). Combining resistance training with energy restriction may result in excessively high cortisol levels. Since cortisol causes a decrease in protein synthesis and an increase in catabolism of cellular proteins (24), elevated cortisol levels may be counter productive for athletes who desire an increase in muscle mass and strength.

Increases in cortisol levels have been associated with an increase in muscle damage following resistance exercise (20). Plasma CK, an indicator of muscle membrane leakage and damage, significantly increased 24 hours after performing varying resistance exercise protocols. The rise in CK 24 hours post exercise was significantly correlated to the rise in cortisol 5 minutes post exercise ( $r = 0.84$ ) for the 10 RM/1 minute rest protocol.

Athletes often experiment with dietary supplements in hope of improving performance and appearance. Out of 309 body builders surveyed, 59% spent \$25-100 per month on supplements (5). Thirty-one percent reported drinking carbohydrate loading drinks. Despite the fact that carbohydrate beverages are marketed for increased performance in weight lifting gyms, there is minimal evidence to support this claim. Lambert et al. (22) studied the effects of consuming a glucose polymer solution versus a placebo before and during knee extension exercises for subjects who were in energy balance. Performance, measured as the number of sets and total work done to exhaustion, tended to improve in the carbohydrate condition ( $p=0.067$  for sets and  $p=0.056$  for repetitions). On the other hand, Conley et al. (10) and Vincent et al. (33) reported that carbohydrate supplementation had no effect on resistance exercise performance. Carbohydrate supplementation may be of more benefit for performance when the athlete is in a negative energy balance. Ingesting carbohydrate before a resistance training session may allow some glycogen synthesis prior to exercise and delay fatigue and increase the total work done.

This study was designed to investigate if carbohydrate supplementation would improve resistance training performance, decrease markers associated with protein catabolism and muscle damage, and reduce rate of perceived exertion in male subjects undergoing energy restriction.

## **METHODS**

**Subjects.** Twenty-two subjects were recruited from local weight lifting gyms in the Blacksburg, Virginia area. All subjects had been weight lifting for at least one year, 3 to 5 times a week. They denied use of steroids in the past year and agreed to stop all amino acid and creatine supplements two weeks before beginning the 11 day study. Eight subjects reported taking a multivitamin daily which they were allowed to take during the study. Two subjects reported taking amino acid supplements and three subjects reported taking creatine supplements prior to participating in the study. One subject reported drinking protein shakes on a regular basis. They were informed of all risks involved and agreed to participate in the study that was approved by the Institutional Review Board. Sixteen of the subjects agreed to undergo energy restriction and blood draws. They were randomly assigned to two experimental groups, a carbohydrate group (C) and a placebo group (P). The remaining six subjects served as a control group (N) to control for possible effects of repeated testing of the resistance training performance. The entire study lasted 11 days. Body fat was assessed using skin folds. The sites were chest, abdomen, and thigh. Measurements were done in triplicate and the mean of each site was used in the equation by Jackson and Pollack (18).

**Diet.** During the first three days of the study, subjects participating in the experimental groups completed diet records. These diet records were analyzed using Nutritionist IV and modified to provide an exchange diet that supplied 60% carbohydrate, 15% protein, and 25% fat. The exchange diets were consumed the day before and the day after energy restriction (Days 7 and 11). These were also the days the subjects had blood drawn.

The energy restriction diet was a formula diet (Ensure, Ross Laboratories) that supplied  $18\text{kcal kg}^{-1} \text{d}^{-1}$  consisting of 54.7% carbohydrate, 21.3% protein, and 24% fat provided for three days (Days 8, 9, and 10). During the energy restriction, subjects picked up their diet each morning and were weighed to the nearest 0.1 kg to ensure compliance. They were told not to consume any other foods or beverages other than water and noncaloric drinks. They were encouraged to drink extensive amounts of water to prevent dehydration.

**Exercise Testing.** All subjects participated in the resistance training workouts and performance tests. The week before starting the study, subjects underwent strength tests. A 10 repetition maximum (10RM) was determined for parallel squats (free weights), bench press (free weights), leg press (Nautilus Inc. Deland, Florida), and one-legged leg extension (Nautilus Inc. Deland, Florida). Exercises were always done in this order. The strength test was done twice with 2 days in between each test. After a five minute warm up on a stationary bike, subjects began the strength test. The 1<sup>st</sup> set was light resistance chosen by the subjects. Subjects then estimated how much resistance was needed for

fatigue to occur after 10 repetitions. After resting two minutes between sets, the weight was adjusted until a 10RM set was performed. During the 1<sup>st</sup> strength test, this took 3 or 4 sets. The resistance used during workouts and performance tests was based on the 10RM.

Subjects participated in standardized resistance workouts every other day during the 11 day study. The workouts consisted of 5 sets of squats, bench press, leg press, and leg extension. The resistance for the five sets of each exercise was 80%, 80% 70%, 60%, and 60% of 10RM. For the standardized workouts, subjects doubled their one-legged leg extension resistance and worked both legs. For each set, subjects performed 10 repetitions. Subjects were asked to rest 2 minutes between sets. These workouts were unsupervised and recorded by the subjects.

The resistance performance tests were very similar to the standardized workouts except the 5<sup>th</sup> sets of bench press and leg extension were done until failure at 80% of 10RM. The number of repetitions performed in these fifth sets were the dependent performance measures. No encouragement was given to subjects during the performance tests. The tests were done on Days 5, 7, and 11 of the study and replaced the standardized workout for those days. All performance tests were done between 7:45 and 10 AM. Day 1 was a practice performance test done under the investigator's supervision to familiarize subjects with doing repetitions to failure. Experimental subjects rode an exercise bike at a comfortable resistance and pace for 3 minutes before Trial 1. Before Trials 2 and 3, subjects walked at a moderately fast pace for 7 minutes from the laboratory to the gym. Control subjects rode an exercise bike before each trial. After this aerobic warm up, subjects did one set of parallel squats at 60% of 10RM and then they started the performance test. The two tests before energy restriction (Trials 1 and 2, Days 5 and 7) were used to determine the reliability of performance measures. The number of repetitions completed during Trial 2 was compared to the test performed after energy restriction (Trial 3, Day 11). Rate of perceived exertion (RPE) was taken after the 5<sup>th</sup> set of every exercise and after the 4<sup>th</sup> set of bench press and leg extension.

Subjects reported to each performance test after fasting for at least 8 hours. They recorded what they ate for dinner and snacks the night before Trial 1 and consumed the exact same dinner and snacks the night before Trial 2. Control subjects repeated this recorded dinner and snacks the night before Trial 3.

On the day of Trial 3 (Day 11), experimental subjects had their blood drawn when they reported to the laboratory and then consumed their assigned beverages 30 minutes prior to the start of the resistance performance test. The carbohydrate group consumed a 1.0 L beverage containing 1 g carbohydrate per kg of body weight (powdered Gatorade, fructose and glucose). The concentration of the solution ranged from 7.0 to 10%. The placebo group consumed a beverage of equal volume and similar color that was sweetened with NutraSweet. This was single blind. The subjects were not told which beverage they received.

**Blood collection and analysis.** Experimental subjects had blood drawn before and after Trials 2 and 3. Subjects reported in a fasted state. For each subject, the 1<sup>st</sup> blood draw for Trial 3 was done within 30 minutes of when blood draws had been started for Trial 2. All blood draws began between 7:15 and 8:15. Seven to 10 ml of blood were drawn from a forearm vein 30 to 60 minutes before exercise, 10 minutes, 6 hours, and 24 hours post exercise. The blood was placed on ice for 30 minutes and then centrifuged so that the serum could be removed and frozen for later analysis of cortisol, CK, and glucose. All samples were analyzed in duplicate. Plasma cortisol was assayed using a competitive solid-phase <sup>125</sup>I radioimmunoassay technique (Diagnostic Products Corporation, Los Angeles, CA). The within assay coefficient of variance was 7.30%. CK activity was determined using a colorimetric assay method, Sigma no. 47-UV (Sigma Diagnostics, St. Louis, MO). Blood glucose was determined using a colorimetric procedure, Sigma #115 (Sigma Diagnostics, St. Louis, MO).

**Statistical analysis.** The performance data and body weight were analyzed using a repeated measures ANOVA. A Tukey post hoc procedure was conducted to make comparisons of means. Diet records were analyzed using a one-way ANOVA to determine if there were differences between groups. Blood parameters were analyzed with a three-way ANOVA. A post hoc analysis of least square means was used to make comparisons of means. A P-value <0.05 was considered significant.

## **RESULTS**

There were no significant differences between groups for age, initial body weight, or height (Table 1). The placebo group had significantly higher initial body fat than the carbohydrate group, but there were no significant differences between groups for lean body mass. Body fat data were not collected from the control subjects. From the analysis of the three day food records, there was no difference in total calories or proportion of carbohydrate, protein, or fat in the diets the two experimental groups at base line (Table 2).

### **Body weight**

Both experimental groups lost a significant amount of body weight due to energy restriction (Figure 1). The subjects lost an average of  $2.24 \pm 0.2$  kg. There was not a difference in weight reduction between groups.

### **Performance**

The reliability of the performance measures was determined by comparing the number of repetitions completed during the fifth set for bench press and one-legged leg extension in Trials 1 and 2. Pearson's Product Moment Correlation shows a correlation of  $R=0.696$  for bench press and  $R=0.847$  for one-legged leg extensions. The variation between Trials 1 ( $15.1 \pm 0.8$  for bench press and  $15.5 \pm 0.7$  for leg extension) and Trials 2 ( $16.0 \pm 0.9$  for bench press and  $16.4 \pm 0.8$  for leg extension) may be due to a learning effect. The number of repetitions performed during Trial 2 was compared to Trial 3 to determine if performance changed due to the treatment beverage. Performance was not enhanced by carbohydrate supplementation. Performance as measured by the number of repetitions

performed during the final set of leg extension showed no interaction between groups and time ( $p=0.801$ ). The number of repetitions performed during the final set of bench press showed significant interaction. The placebo increased the number of repetitions performed from Trial 2 to Trial 3 ( $15.0 \pm 1.4$  to  $17.3 \pm 0.8$ ), but this not significant. The control group significantly increased the number of repetitions performed from Trial 2 to Trial 3 ( $15.0 \pm 2.7$  to  $16.7 \pm 2.3$ ). The carbohydrate group significantly decreased the number of repetitions performed ( $17.6 \pm 0.7$  to  $17.3 \pm 1.0$ ). It should be noted that P and N performed fewer repetitions during Trial 2 than was completed by C. Performance data are shown in Figures 2 and 3.

RPE during the resistance performance test was not affected by weight loss or carbohydrate supplementation. When the groups were collapsed, RPE was significantly lower after the 5<sup>th</sup> set of parallel squats during Trial 3 compared to Trial 2 ( $11.1 \pm 0.54$  for Trial 2 versus  $9.7 \pm 0.51$  for Trial 3). RPE was significantly higher after energy restriction compared to before after the 5<sup>th</sup> set of leg press ( $11.0 \pm 0.4$  during Trial 2 versus  $12.2 \pm 0.6$  during Trial 3) and the 5<sup>th</sup> set of leg extension ( $16.4 \pm 0.3$  during Trail 2 versus  $17.0 \pm 0.4$  during Trial 3). These changes in RPE cannot be attributed to energy restriction since there was no interactions between the experimental groups and the control groups. RPE for bench press was not significantly changed during the 4<sup>th</sup> set ( $8.8 \pm 0.5$  versus  $8.4 \pm 0.4$ ) or 5<sup>th</sup> set ( $16.0 \pm 0.4$  versus  $16.6 \pm 0.51$ ). RPE was not changed during the 4<sup>th</sup> set of leg extension ( $10.5 \pm 0.5$  versus  $9.8 \pm 0.5$ ).

#### Blood Analysis

Serum glucose levels were not affected by carbohydrate supplementation (Figures 4 and 5). There was trend for glucose to be higher during Trial 2 than Trail 3 when the groups were collapsed ( $p=0.06$ ). A post-hoc analysis did not identify any a significant difference between trials for pre or post exercise. Serum glucose was non significantly higher after exercise during Trial 2 for both groups and non significantly lower after exercise during Trial 3 for both groups. Serum glucose 6 hours post exercise tended to be lower after Trial 3 compared to after Trial 2 ( $p=0.057$ ).

Serum cortisol levels were not affected by carbohydrate supplementation (Figures 6 and 7). Cortisol was lower after exercise and decreased more at six hours post exercise. However, since there was not an non-exercising control group, it cannot be determined if cortisol was lower due to exercise or simply because of diurnal variation. When groups were collapsed there was a significant difference in cortisol response on the day of Trial 2 compared to the day of Trial 3. A post hoc analysis to determine which blood draw was different revealed that the only significant difference was in resting cortisol levels. When the data for both experimental groups were collapsed, there was a significant increase in pre exercise cortisol levels following energy restriction ( $252.1 \text{ nmol/L} \pm 12.0$  versus  $306.5 \text{ nmol/L} \pm 17.0$ ). There was a significant group effect with C having higher cortisol levels during the study compared to P. There was no interaction between groups and trials (Trial 2 or 3) or groups and time of blood draws.

There was an increase in CK after exercise when experimental groups were collapsed for

Trials 2 and 3 (Figures 8 and 9). During Trial 2, CK was elevated 16% 10 minutes post exercise and 54% 6 and 24 hours of 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. The changes in CK levels that occurred post exercise were not affected by energy restriction or carbohydrate supplementation.

## **Discussion**

Carbohydrate supplementation did not improve resistance training performance in this study. Numerous studies have shown that carbohydrate ingestion delays fatigue during endurance exercise. Mechanisms suggested to explain the ergogenic effect of carbohydrate include maintenance of blood glucose permitting high rates of carbohydrate oxidation (9) and muscle glycogen sparing (14). One study has reported a trend towards improved performance during resistance exercise when a glucose polymer solution versus a placebo was ingested before and during leg extension exercises (22). The resistance was 80% of 10RM and subjects performed 10 repetitions per set until the 10<sup>th</sup> repetition could not be fully extended. The next consisted of 9 repetitions. This continued until subjects could not extend the 8<sup>th</sup> repetition to 170 degrees. Subjects rested three minutes between sets. Performance was measured by number of sets ( $p=0.067$ ) and number of repetitions ( $p=0.056$ ). Another study reported that consumption of a carbohydrate beverage (100g CHO) versus a placebo immediately prior to exercise did not increase isokinetic performance after a free weight workout (33). The free weight workout consisted of multiple sets of squats, leg press, leg extensions, calf press, barbell curl, preacher curl, and dumbbell curl. Each set consisted of 12 to 15 repetitions with 60 seconds between sets. After the free weight workout, subjects performed isokinetic knee extensions and forearm flexors for 3 sets of 15 repetitions. There was no significant difference observed in total work done, average power, peak torque, and work fatigue between the carbohydrate and placebo trials. Additionally, Conley et al. (10) saw no effect of consuming a carbohydrate versus a placebo beverage when parallel squats were performed for sets of 10 repetitions at 65% of 1RM until 10 repetitions could no longer be attained. Subjects consumed the beverages 15 minutes before exercise and after every successful set of 10 repetitions. There was no difference in the number sets, repetitions, or total work done. Conley and Stone (11) hypothesized that during this study, 35 minutes was not long enough for carbohydrate to become a limiting factor, but in the 56 minutes of the Lambert et al. (22) study, carbohydrate availability may have become limiting. Thus the reason why a trend towards improved performance was reported. Perhaps during the 50 minutes of exercise of the current study, carbohydrate availability was not limited. Future studies may want to look at longer periods of exercise to see the effect of carbohydrate on resistance training performance.

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 repetition. 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.

Energy restriction did not impair resistance training performance during this study. All groups showed an increase in the number of repetitions performed during leg extension and the placebo and control groups improved the number of repetitions performed during bench press from Trial 2 to Trial 3. This increase in performance may be related to a learning effect. Subjects only had a chance to perform this workout three times before Trial 2. There was one standardized workout between Trials 2 and 3. The subjects may have been more familiar with the workout during Trial 3 thus attributing to the increase in performance.

It is hypothesized that muscle glycogen levels were lower after three days of energy restriction during the current study. Since, muscle biopsies were not taken, this cannot be confirmed. Other studies have reported that energy restriction decreases performance and reduces muscle glycogen levels. After a group of wrestlers reduced their caloric intake by 66% and decreased their body weight by 2.2% in 48 hours, their muscle strength was reduced (16). This was concurrent with a significant reduction in muscle glycogen concentration (29%). Tarnopolsky et al. (29) also reported a 54% decrease in muscle glycogen concentration after a group of highly trained wrestlers underwent energy restriction for 3 days and lost 5% of their body weight.

The lack of effect of energy restriction on performance may be because muscle glycogen levels were not reduced or the intensity of the workout may not have caused further reductions. Studies that have reported significant decreases in muscle glycogen following resistance exercise used high intensity protocols (12, 30). Both of these studies used resistance that caused muscle failure within 6 to 12 repetitions. It may be that a higher intensity is needed to produce significant decreases in muscle glycogen levels. The volume of work done is also related to decreases in muscle glycogen. Robergs et al. (27) reported that muscle glycogen decreased in almost equal amount whether subjects performed leg extensions at 70% of 1RM or 35% of 1RM. Force accumulation and external work were the same for each trial because subjects performed more repetitions during the lower intensity trial. MacDougall et al. (23) reported that after one set of biceps curls done at 10RM to failure, muscle glycogen was reduced 13%. And following 3 sets it was reduced 25%. A workout that uses either a high volume or high intensity resistance may be needed to achieve a reduction in muscle glycogen levels that results in impaired resistance exercise performance.

Energy restriction seems to have affected blood glucose levels after exercise. The decrease in blood 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 was lower at the start of Trial 3 more blood glucose may have been used to provide substrate for glycolysis.

This study found that cortisol levels were significantly elevated following three days of a hypoenergy diet. The 21.6% increase in resting cortisol levels is lower than the two fold increase due to fasting reported in previous studies (3, 4). Since the main metabolic function of cortisol is to stimulate gluconeogenesis, it appears that low energy intake causes an increase in cortisol to provide more carbohydrate for the body's energy requirements. This may have negative consequences for resistance trainers because cortisol decreases protein synthesis and increases protein catabolism (24). Chronically elevated levels of cortisol due to energy restriction may impair the ability of resistance trainers to increase muscle mass and strength. Future studies should examine cortisol levels during the period of preparation for competitions when body builders are dieting to reduce their subcutaneous fat.

Serum cortisol levels were not increased after a resistance exercise bout in this study. In spite of the likely lower body carbohydrate stores and the potential increased need for glucose, energy restriction did not cause an increase in cortisol levels following exercise. The decrease in cortisol levels 10 minutes and 6 hours post exercise can be attributed to diurnal variance since cortisol levels tend to be highest in the morning and lower in the afternoon. The changes in cortisol levels cannot be attributed to exercise since there was not a non-exercise control group to compare cortisol response to exercise and no exercise. Studies that have reported increases in cortisol levels in trained subjects after resistance exercise have utilized high resistance and short rest periods (20, 21) Kraemer et al. (20) reported an increase in cortisol following a multiple exercise bout that consisted of 10RM resistance with one minute of rest between sets. When the length of rest was increased to three minutes, cortisol levels were not elevated. When the duration of force production was reduced (5RM) there was no increase in cortisol whether the rest period was one or three minutes.

The lack of cortisol response to resistance exercise in the current study may be due to a lower intensity (80, 70, and 60% of 10RM) or longer rest intervals (2 minutes). The mechanism for increasing cortisol levels during resistance training has not been identified, but the research is consistent in showing that longer rest periods prevent the increase in cortisol levels following exercise. Guezennec et al. (13) reported no increase in cortisol levels following bench press exercises performed at 70% of maximal performance with 3:45 rest between sets. When subjects rested three minutes between sets of parallel squats performed at 65% of 1RM there was no increase in cortisol levels post exercise (26).

CK levels were significantly elevated following a resistance exercise bout in the current study. This 50% increase in CK levels 24 hours after exercise was similar to increases reported by Kraemer et al. (20) for all protocols except the 10RM with 1 minute rest. The higher force production and shorter rest interval protocol in that study resulted in a three fold increase in CK and significantly elevated cortisol levels post exercise. It was this protocol that had the highest increase in cortisol levels. It is reasonable to assume that if the protocol used in the current study had significantly increased cortisol levels, CK may also have been higher.

Creatine kinase levels were not affected by energy restriction or carbohydrate supplementation. Several studies have examined whether carbohydrate ingestion influences CK response to aerobic exercise. Cade et al (7) reported a carbohydrate electrolyte drink consumed before a swim workout reduced the increase in CK in competitive swimmers who performed two hour workouts twice a day. In contrast, Tsintzas et al (31) reported that CK levels were significantly higher 24 hours post exercise when subjects consumed 3 ml kg<sup>-1</sup> of a 5.5% carbohydrate solution versus water immediately prior to the start of running 42.2 km and 2.5 ml kg<sup>-1</sup> every 5 km during the run. The researchers reported that the higher intensity maintained near the end of the run during the 5.5% carbohydrate trial may be responsible for higher CK levels. Kirwan et al. (19) reported that CK levels after intense training were not affected by the amount of carbohydrates athletes consumed for 5 days. After running for about 80 minutes a day at about 80% of VO<sub>2</sub>max for five days, CK levels were significantly elevated. Consuming carbohydrates estimated to be equal to (8g CHO/d) or below (3.9g CHO/d) energy expenditure resulted in no significant differences in CK levels between different diet regimens. From these studies and the current study, the effect of carbohydrate prior to exercise on CK levels is unclear.

The lack of effect of carbohydrate supplementation on RPE during this study may relate to the amount of time involved in the exercise protocol. Carbohydrate supplementation versus a placebo did not affect RPE during the first 80 minutes of a cycling bout at 70% of VO<sub>2</sub>max (28). At 100, 120 and 140 minutes, RPE was lower for the carbohydrate trial. This was also the time interval during which blood glucose levels were significantly different between groups. Burgess et al. (5) also noted a relationship between higher blood glucose levels and lower RPE. This was evident only after two hours of exercise. Thus it seems that the benefit of carbohydrate supplementation on RPE is seen only during prolonged exercise. During the current study the exercise protocol lasted just 50 minutes. This may not have been sufficient time to experience changes in blood glucose levels and/or RPE. The lack of change in RPE may also be associated with the fact that a decrease in blood glucose is usually not observed during resistance exercise (17). For resistance exercise bouts that last one hour or less, carbohydrate supplementation probably will not affect RPE.

In the current study, RPE was not increased after energy restriction. One study has reported an increase in RPE during intermittent anaerobic exercise following energy restriction (15). Subjects lost 6.3 ± 0.3% body weight following the low carbohydrate diet (41.9% carbohydrate, 11.4% protein, 41.9% fat) and 6.2 ± 0.3% body weight following the high carbohydrate diet (65.9% carbohydrate, 11.4% protein, 22.7% fat). RPE was higher following energy restriction in that study, but there was no difference between the two diets for RPE. The weight loss in the current study was less than that reported by Horswill et al. (15). Additionally, the subjects in the Horswill study also did dehydration. There may be a threshold effect for energy restriction and increased rates of perceived exertion.

In summary, ingesting 1g carbohydrate  $\text{kg}^{-1}$  30 minutes prior to resistance exercise did not affect blood glucose, cortisol levels, CK levels, or RPE in males undergoing energy restriction. Additionally, resistance exercise performance was not improved. Carbohydrate supplementation prior to resistance exercise was not found to be beneficial. CK levels were significantly higher following resistance exercise, suggesting muscle damage. Energy restriction did not influence the extent of muscle damage but increased resting cortisol levels. This is one reason resistance trainers should avoid severe energy restriction.

Table 1. Description of groups

Group	Age (years)	Weight (kg)	Height (cm)	Body Fat (%)	Lean Body Mass (kg)
Carbohydrate (n=8)	21.8 (.8)	84.2 (3.0)	180.7 (2.5)	10.6 (1.3)*	75.1 (2.2)
Placebo (n=8)	20.5 (.6)	84.4 (3.5)	181.9 (3.0)	14.2 (1.0)	72.2 (2.3)
Control (n=6)	22.2 (.8)	78.9 (4.7)	179.5 (2.4)	-----	-----

Values are means  $\pm$  SEM. \*Indicates significant difference between groups.

Table 2. Dietary measurement of data from diet records

Group	Energy (kcal)	Carbohydrate (%kcal)	Protein (%kcal)	Fat (%kcal)
Carbohydrate (n=8)	3071.3 (157.4)	56.9 (4.7)	19.1 (2.4)	24.0 (2.9)
Placebo (n=8)	2620.0 (268.3)	56.8 (3.7)	15.1 (1.0)	27.9 (3.7)

Values are means  $\pm$  SEM. There were no difference between groups.

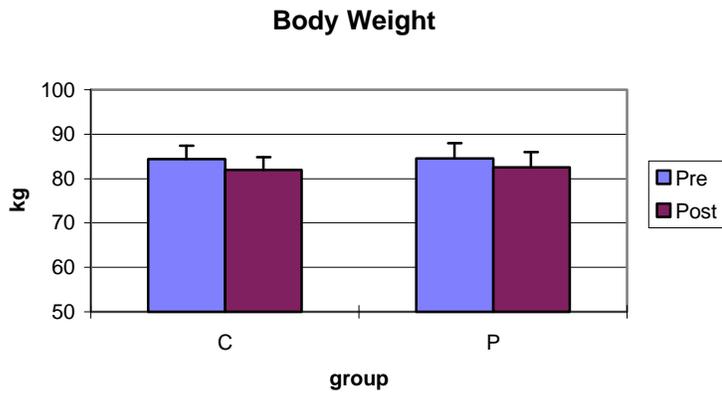


Figure 1 Mean body weight before and after energy restriction. C = carbohydrate group and P = placebo group. There was a significant decrease in body weight over time when groups were collapsed, but there were no differences between groups over time.

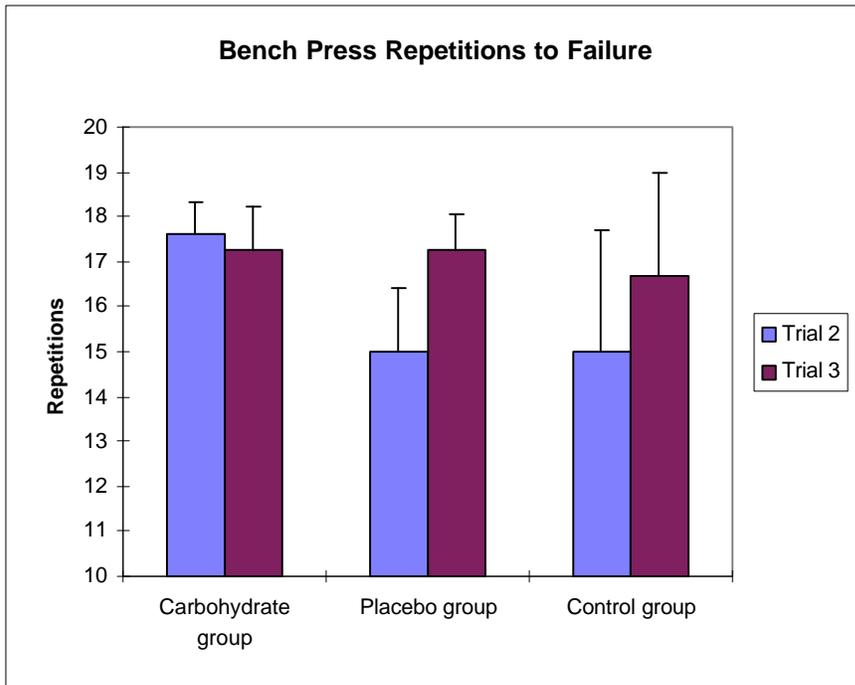


Figure 2 Average number of bench press repetitions to failure completed by each group before and after energy restriction. There was significant interaction between groups and trials.

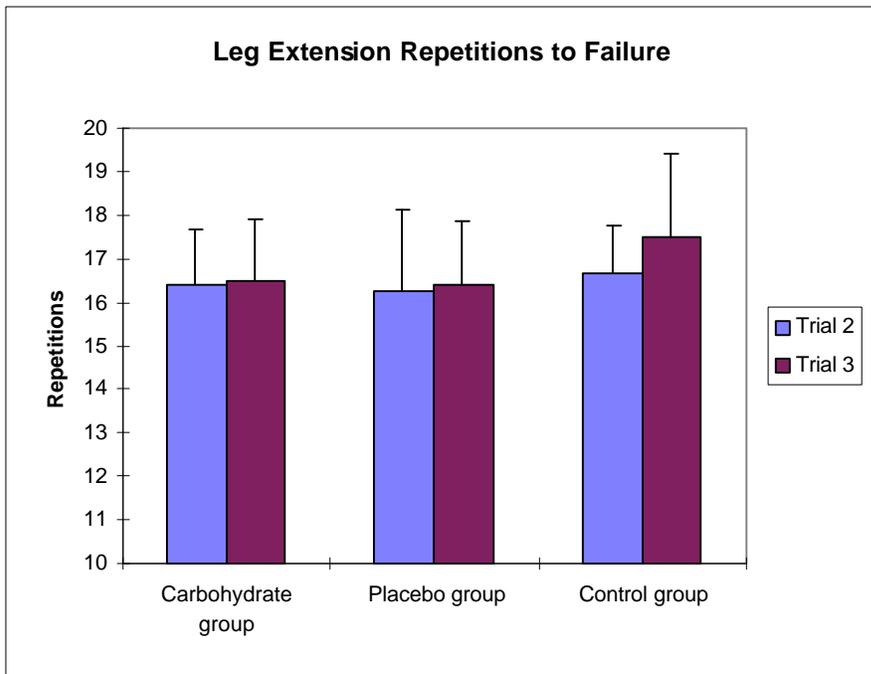


Figure 3 Average number of one-legged leg extension repetitions to failure completed by each group before and after energy restriction. There were no difference between trials or groups.

### Blood Glucose Before and After Trial 2

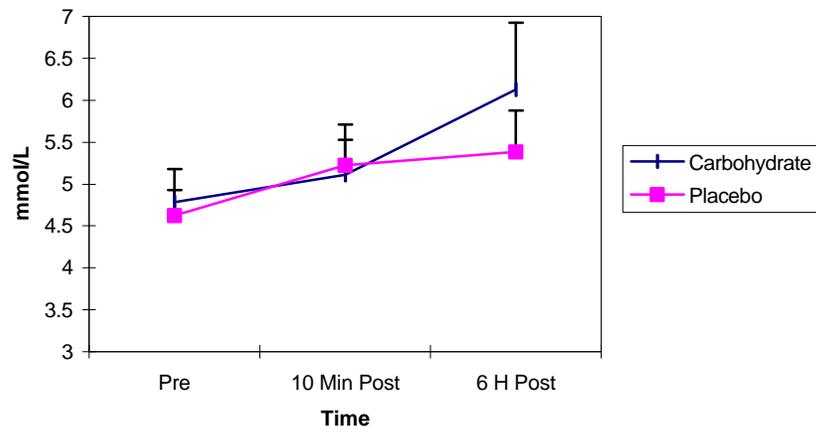


Figure 4 Blood glucose (mean  $\pm$  SEM) before and after exercise on the day of Trial 2. There were no differences between groups.

### Blood Glucose Before and After Trial 3

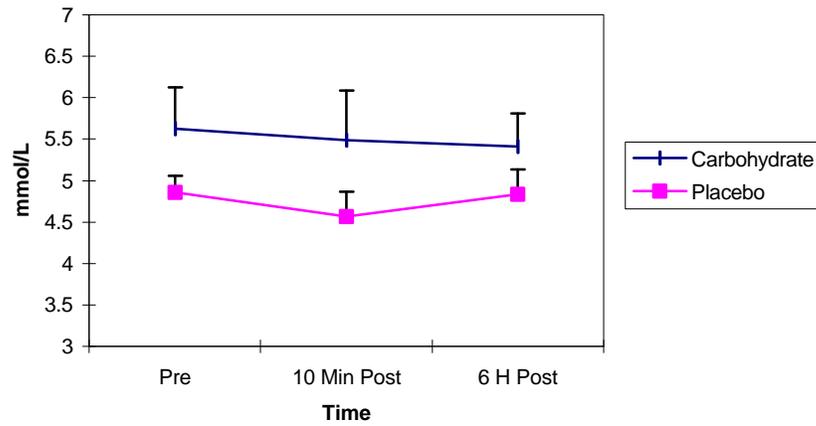


Figure 5 Blood glucose (mean  $\pm$  SEM) before and after exercise on the day of Trial 3. There were no differences between trials or groups.

### Cortisol Response Before and After Trial 2

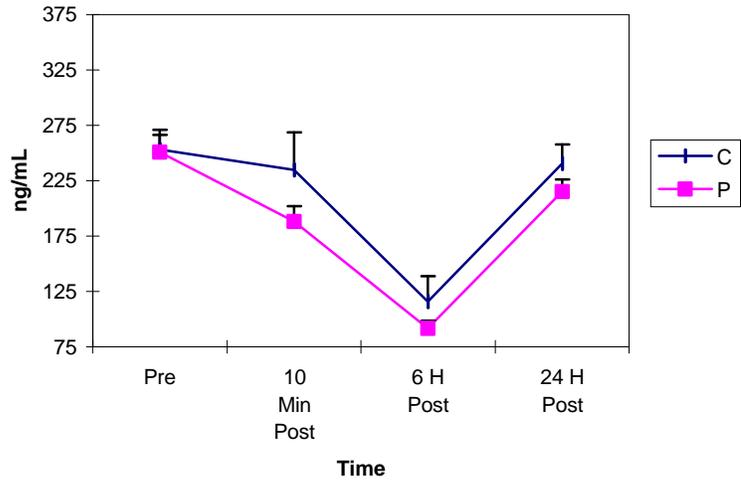


Figure 6. Cortisol response before and after exercise during Trial 2. C = carbohydrate group and P = placebo group. There was no significant differences between groups.

### Cortisol Response Before and After Trial 3

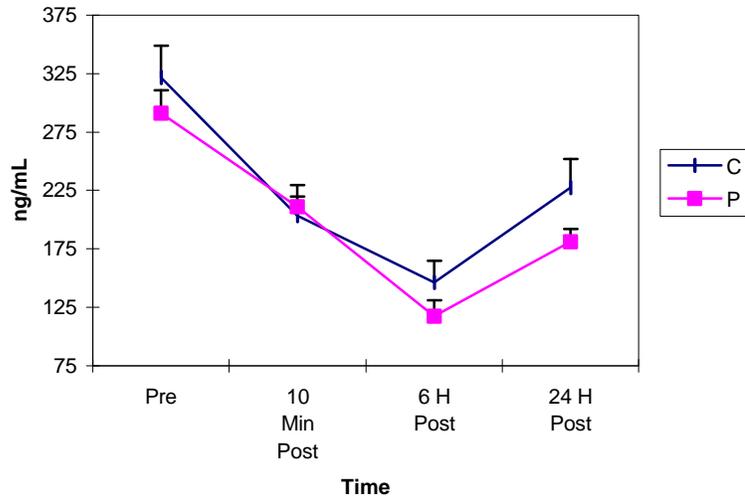


Figure 7. Cortisol response before and after exercise during Trial 3. C = carbohydrate group and P = placebo group. There was no significant differences between groups. Cortisol levels were significantly higher pre exercise during Trial 3 versus during Trial 2.

### CK Before and After Trial 2

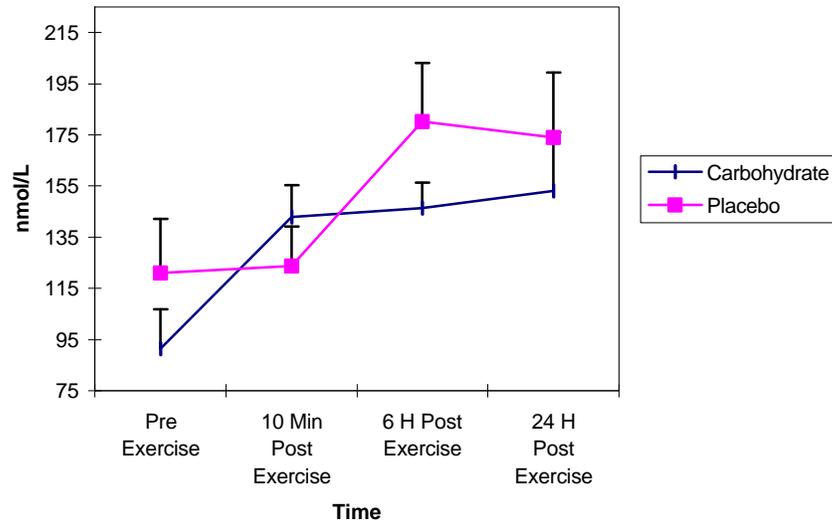


Figure 8 CK response before and after exercise during Trial 2. CK was significantly higher after exercise at all points compared to pre exercise levels for the carbohydrate group. CK was significantly higher for the placebo at 6 and 24 hours after exercise as compared to pre exercise levels. There were differences between groups.

### CK Before and After Trial 3

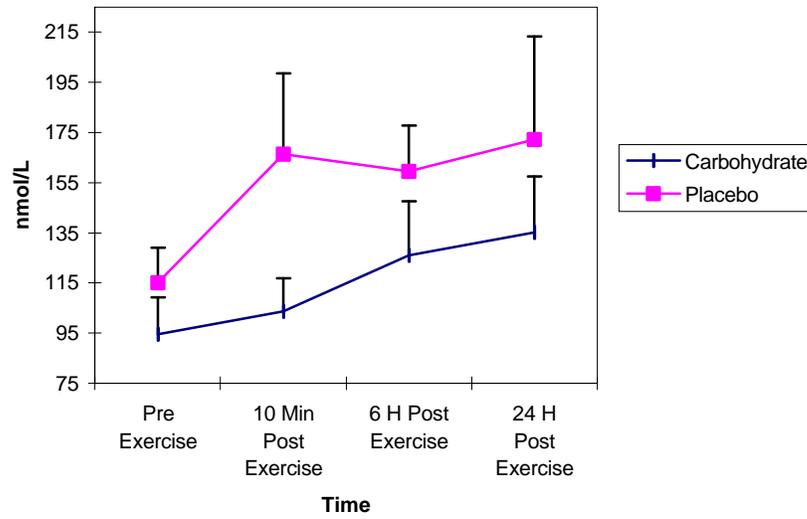


Figure 9 CK response before and after exercise during Trial 2. CK was significantly higher after exercise at all points compared to pre exercise levels for both groups. There were no differences between groups.

## References

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