University of Alberta

Body composition and performance changes following 8-weeks of carbohydrate or whey isolate protein-carbohydrate supplementation and concurrent resistance training

by

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A thesis submitted to the Faculty of Graduate Studies and Research in partial fulfillment of the requirements for the degree of Master of Science

Faculty of Physical Education and Recreation

Edmonton, Alberta
Spring 2004

Your file Votre référence
ISBN: 0-612-96553-8
Our file Notre référence
ISBN: 0-612-96553-8

ABSTRACT

Purpose: The purpose of this study was to assess the changes in body composition and strength performance when combining resistance training with the ingestion of a mixture of whey isolate protein (*Protient, ST. Paul, Minnosota)* and carbohydrate or carbohydrate only in male recreational weight trainers.

Methods: Twenty-five participants were randomly assigned to a whey isolate protein and carbohydrate (ProCarb; 1.64g • kg^{-1} • day^{-1}, n = 12) or an isoenergenic carbohydrate (Carb; n = 13) group. Both groups participated in resistance training four times per week for eight weeks. Body composition (DEXA) and strength 1-RM measures were assessed pre and post training. Three-day dietary records were recorded at baseline, and during the third and eighth week of training.

Results: Total body mass, total lean body mass, leg lean body mass, arm lean tissue mass and upper body lean tissue mass were significantly increases to a similar extent for both groups after training. Fat mass, body fat %, and trunk lean tissue mass did not change. 1-RM bench and leg press increased significantly with training in both groups with no difference between the groups.

Conclusion: Males who resistance trained and concurrently supplemented with either whey isolate protein-carbohydrate or carbohydrate over an eight week period experienced similar significant improvements in strength and body composition. This study also revealed no significant change in total body fat or percentage body fat.

DEDICATION

To My Beautiful and Loving Wife

ACKNOWLEDGMENT

At the current time I would like to that the people that have influenced and helped me achieve this accomplishment. First, I would like to thank my advisor, Dr. Dan Syrotuik. Dan, that you very much for your support, direction, patience, insight, and respect. Most of all, that you for having your door open and greeting me with a genuine desire to know how I was. As well, thank you for sharing with me a story, or two, when I needed to hear one. I guess I am on the right side of a M.Sc. now, eh Tuck. Dr. Gordon Bell, Gord thank you as well for your help, direction and time. Gord, I enjoyed every picture and look forward to see more in the future. Dr. Linda McCargar, thank you for being on my committee and providing the use of the Human Nutrition Laboratory and it's excellent staff. I would also like to acknowledge and thank Protient of ST. Paul Minnesota for their support in this research.

To my friend Chris Robinson, thank you for your enthusiasm, humor, and inspiration. Chris, you know how far we have come. I look forward to where we are going.

To my parents, thank you for your love, prayers and support.

To my wife Linda, you have provided so much support and have given so much. Thank you for being there whenever I needed you. I love you very much.

Finally, I would like to thank all the people who participated in this study. Thank you for your commitment and enthusiasm.

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CHAPTER 1

Introduction

1.1 Introduction

Increases in muscle mass may pose benefits to athletes and recreational weight lifters as well as to elderly and bedridden individuals. Numerous investigations have looked into the anabolic and catabolic events of muscle protein metabolism as a result of resistance exercise. An important influence for increases in skeletal muscle is the availability of amino acids. Controversy exists over the exact amount of protein athletes need, however, suggested protein intakes range from those slightly above to four times that of non-athletic individuals (Tarnopolsky et al., 1992). Recently, there have been a growing number of studies that have examined the acute metabolic responses of ingesting supplements containing amino acids and carbohydrates during resistance exercise (Gibala, 2000; Houston, 1999; Miller et al., 2003; Tipton and Wolfe, 2001). A number of these studies have provided empirical evidence for improved increases in muscle mass when supplementing with amino acids (Chandler et al., 1994; Kraemer et al., 1998; Tipton et al., 1999) or when combining amino acids and carbohydrates (Chandler et al., 1994; Esmarck et al., 2001; Kraemer et al., 1998; Rasmussen et al., 2000).

Addition of carbohydrate to a supplement while resistance training may add further benefits for increases in muscle mass and strength. The benefits may be a result of an increase in the anabolic hormone insulin. Research has shown that insulin enhances the protein synthetic process and uptake of amino acids for protein synthesis (Jefferson et al., 1980). The mechanism of the insulin action on protein synthesis involves a direct activation of the protein synthetic process at the nuclear and cytoplasmic levels (Kimball et al., 1988). As well, insulin decreases the rate of protein degradation following a bout of exercise (Biolo et al., 1999). Although the aforementioned studies have suggested that supplementation of amino acids and carbohydrate may have provided benefits for increases in muscle mass while resistance training; little work has been done to test these claims over a multi-week or long term training period.

Most recently, whey protein has become a highly marketed and popular protein supplement for weight trainers. Many athletes are utilizing this “over the counter” product with the belief that it will enhance their strength and muscle mass over training alone. A review of literature indicates that five studies have examined the effects of resistance training combined with whey protein supplementation on body composition, muscle mass and strength (Agin et al., 2001; Burke et al., 2001; Colker et al., 2000; Demling et al., 2000; Kreider et al. 2003). No study has studied the effects of combining multi-week or longer-term resistance training with whey isolate protein-carbohydrate supplement on body composition, muscle mass and muscular strength.

1.2 Significance of Study

The use of nutritional supplements is a popular practice among competitive and recreational athletes. Some reports have indicated that 59% of athletes reported the use of nutritional supplements as a means to gain an edge over their competitors (Maughn, 2001). Some surveys have also indicated that 100% of weight lifters have used some form of nutritional supplement (Burke et al., 1993). Whey protein has become a highly marketed and popular supplement among athletes. Most weight lifting athletes are consuming whey protein with the belief that it will provide them with greater gains in muscle mass and strength than training alone; however, few studies have supported this claim.

Commercial supplement products consisting of a combination of carbohydrate and protein are now being marketed to weight training athletes. New research has also indicated that the addition of carbohydrate to a protein supplement elicits a greater anabolic environment than protein or carbohydrate consumed alone (Miller et al., 2003). However, little work has been done investigating the effects of combining weight training and supplementing with protein and carbohydrate over a multi-week period (Rozenek et al., 2002). As well, no study has looked at the effects of combining weight training with a whey isolate protein and carbohydrate mixture.

In light of the limited research assessing whey isolate protein-carbohydrate as a nutritional training supplement, further research is needed to help improve our understanding of the potential changes in body composition and physical performance associated with these supplements when combined with resistance training over a multi-week period.

1.3 Purpose

The purpose of this study was to assess the changes in body composition and strength performance when combining resistance training with the ingestion of whey isolate protein-carbohydrate or carbohydrate in male recreational weight trainers.

1.4 Hypothesis

It is hypothesized that those trainees who supplement with whey isolate protein and carbohydrate mixture while resistance training, will have greater increases in muscle mass and strength than those trainees who supplement with carbohydrate only.

1.5 Delimitations

1) Potential male subjects will be recruited from the University of Alberta's male population. The criterion for participation in the study includes: current participation in a resistance training routine for a minimum of 3 months, no current or reported use of hormonal supplements, and not currently consuming protein and/or carbohydrate supplements.
2) The independent variables in this study include the resistance training load and the treatment of supplementation.
3) The dependent variables in this study include body composition (lean body mass and fat mass), and muscular strength (1-RM).

1.6 Limitations

1) Participants will not be randomly selected to be subjects in the study as they will be individuals who came into contact with a written advertisement.
2) Participants will be recruited from the University of Alberta's male population and therefore may not truly represent the general male population of other regions of the world.

3) The consumption of supplements will not always be supervised and will be based on trust. It is possible that some participants will not consume the supplements regularly.
4) The use of dietary questionnaire relies on the accurate reporting of the subjects.
5) Dual energy x-ray absorptiometery is an indirect measurement of body composition.

CHAPTER 2

Review of Related Literature

2.1 Introduction

Increases in skeletal muscle mass and muscular performance are sought after by many elite athletes, recreational weight lifters, patients rehabilitating atrophied muscle and for the elderly to maintain or improve functional living. To attain optimal increases in skeletal muscle one needs an appropriate combination of resistance training, diet, and rest (Houston, 1999). Researchers have indicated that the most potent initiator of muscle protein synthesis is the combination of resistance exercise and elevated amino acid availability (Biolo et al. 1997). However, because elevated levels of circulating insulin apparently inhibit muscle protein breakdown following resistance exercise, it appears that the addition of carbohydrates to a meal or supplement containing amino acids may increase muscle anabolism further to that of amino acids alone (Tipton and Wolfe, 2001).

For muscle hypertrophy to occur, the metabolic events in skeletal muscle must result in an overall net increase in muscle protein synthesis. Thus, muscle protein degradation must be less than muscle protein synthesis. Heavy resistance training has been shown to increase protein synthesis (Biolo et al., 1995; Chesley et al., 1992; Phillips et al., 1999; Yarasheski, 1993), and increase protein breakdown (Biolo et al., 1995; Phillips et al., 1999). Research has indicated that if untrained subjects remained in a fasted state after resistance exercise, net protein balance (Protein synthesis – Protein breakdown) remains negative, thus representing a state of protein breakdown (Biolo et al., 1995; Phillips et al., 1995). Resistance training has also resulted in a negative protein balance in trained subjects (Phillips et al., 1999). Although resistance exercise has been shown to cause a negative protein balance, Tipton et al. (1999) have shown that if an amino acid solution was ingested, a positive net protein balance was produced.

It is generally understood that ingestion of carbohydrate in non-diabetic healthy individuals results in the production and release of the hormone insulin from the pancreas. Skeletal muscle synthesis and degradation is sensitive to the presence and level of circulating insulin in the blood (Rooyackers and Nair, 1997). When experienced weight lifters ingested a solution of carbohydrate (1.5g • kg of body weight^{-1} • day^{-1}) after resistance exercise, significant elevations in plasma insulin levels were reported (Chandler et al., 1994). Researchers have also shown that higher amounts of circulating insulin, as a response to carbohydrate ingestion, resulted in decreased markers of muscle breakdown (Roy et al., 1997).

When ingesting a mixture of carbohydrate and protein one and three hours after strength training, Rasmussen et al. (2000) discovered that protein synthesis markers were more than double those for protein degradation, thus representing a state of muscle anabolism. Kraemer et al. (1998) have also found that ingesting a protein-carbohydrate supplement over consecutive days after resistance training elicited a hormonal response favorable for muscle protein synthesis.

Five studies are known to have investigated the effects of providing a whey protein supplement combined with resistance training on muscle mass and strength (Agin et al., 2001; Burke et al., 2001; Colker et al., 2000; Demling et al., 2000; Kreider et al.2003). No studies have investigated the effect of a whey isolate protein supplement combined with carbohydrate and resistance training on muscle mass.

2.2 Protein Recommendations During Resistance Training

Previous studies have assessed the effect of essential and non-essential amino acids as a nutritional supplement as well as the protein needs for individuals participating in resistance exercise. Lemon et al. (1992), assessed the protein requirements for strength athletes performing intensive resistance exercise in the early stages of training. During a one-month assessment, subjects participated in an intensive six day per week (3-day split routine) and supplemented with 1.5g • kg of body weight^{-1} • day^{-1} of protein consisting of calcium caseinate and free amino acids. Although there were no significant differences in strength and muscle mass gains between the protein supplemented treatment and the comparison treatment (1.5g carbohydrate • kg of body weight^{-1} • day^{-1}), researchers indicated through nitrogen balance assessments that the protein needs for resistance training athletes should be greater or equal to 1.43g • kg^{-1} • day^{-1} to produce a balanced nitrogen balance. Lemon, et al. (1992), recommended that protein intakes should be 1.6g • kg^{-1} to 1.7g • kg of body weight^{-1} • day^{-1} for weight training athletes. This recommendation was based on the fact that protein intakes are typically based on the mean protein intake for a zero nitrogen balance + 2 standard deviations. These researchers also noted that the duration of the intervention might have been too short to reveal the full benefits of protein supplementation. Recently, the American College of Sports Medicine has also recommended protein intakes of 1.6 to 1.7 g • kg per day^{-1} for weight training individuals (ACSM et al., 2000).

In another study assessing the protein needs of experienced weight training athletes, Tarnopolsky et al. (1988) recommended slightly lower protein intakes than Lemon and co-workers. After assessing six male weight trainees, Tarnopolsky et al.

(1988) noticed individual differences in the level of protein needed to attain a nitrogen balance. Due to the individual differences, researchers recommended a safety margin be included when suggesting levels of protein intake. The researchers recommended a protein intake of 1.2g • kg per day^{-1} for a population of weight training athletes. A safety margin was implemented in the previous recommendations because high protein intake may contribute to kidney degeneration. However, since this recommendation, Poortmans and Dellalieux (2000) revealed no impairment to renal function for protein dietary intakes under 2.8g • kg of body weight^{-1} • day^{-1}.

2.3 Protein Synthesis and Breakdown

For muscle hypertrophy to occur the metabolic events present in skeletal muscle must result in an overall net increase in muscle protein synthesis. Since it is well known that chronic heavy resistance training can lead to gains in muscle hypertrophy, researchers began to investigate the effect resistance training has on muscle protein synthesis. Chesley et al. (1992) examined the magnitude and time course of changes in muscle protein synthetic rates in trained subjects after a single bout of resistance exercise. Muscle protein synthesis was assessed at 4 and 24 hours post-exercise by the increment in L-[1-^{13}C]leucine incorporation into muscle biopsy samples. Measurements revealed that performing three exercises (80% of 1-RM) consisting of four sets of 6-12 repetitions for the biceps increased muscle protein synthesis up to 24 hours post-exercise. In a follow-up study using the same methods to the previous investigation, researchers revealed that muscle protein synthesis was elevated 50% and 109 % at 4 and 24 hours post-exercise respectively and then declined to near basal levels (14% increase) at 36 hours post-exercise (MacDougall et al., 1995).

Resistance training has also been shown to cause a concomitant increment in protein breakdown. Using stable isotopic tracers of amino acids in combination with the assessment of muscle biopsy samples, Biolo et al. (1995) were able to determine the rates of protein synthesis and protein breakdown in response to a bout of intensive resistance exercise in untrained post-absorptive volunteers. Although muscle protein synthesis was increased by a greater margin to that of muscle protein breakdown, the protein balance did not shift to a positive value. The researchers indicated that physical exercise could restrain net muscle protein catabolism but does not directly promote net protein deposition in the post-absorptive state and that exercise needs to interact with other factors such as feeding to promote muscle anabolism.

When investigating the effects of an intravenous infusion of amino acids on protein synthesis while in resting conditions, Biolo et al. (1997) found that muscle protein synthesis was increased. This finding lead researchers to investigate if an oral solution of amino acids would affect net muscle protein synthesis after a bout of resistance exercise (Tipton et al., 1999). After ingesting 40g of essential or mixed amino acids, protein synthesis was increased to that of a placebo condition. Protein synthesis was ~ 70 and ~50% greater for the mixed amino acid and essential amino acid solution, respectively, than a placebo condition. In the same study, researchers revealed that muscle intracellular amino acid concentrations were increased by amino acid ingestion. It was also suggested that increased availability of amino acids was the primary mechanism for the increase in muscle protein anabolism observed when subjects consumed amino acids.

Oral consumption of amino acids has also been shown to influence protein breakdown. While investigating the effects of amino acid supplementation on amino acid and ammonia metabolism during exercise, MacLean et al. (1994) found that if exercising males ingested amino acids (77 mg/kg of body weight) prior to exercise, muscle protein breakdown was suppressed. The researchers also indicated that simply ingesting amino acids resulted in a significant uptake of amino acids into the muscle, and a further elevation of amino acid uptake into the muscles was seen after the initiation of exercise.

2.4 Protein Supplementation and Exercise

When assessing the effect of a protein supplement with resistance training in older adults, the benefits have been equivocal. Campbell et al. (1995) assessed the effects of consuming a diet which provided 0.8g protein • kg^{-1} • day^{-1} (low protein) and 1.6g protein • kg^{-1} • day^{-1} (high protein) combined with a twelve week resistance training program in older (56-80 yr) untrained men and women. Resistance training included performing three sets of upper body (chest press and lat pulldowns) and lower body (knee flexion and extension) exercises at 80% of 1-RM three days per week for twelve weeks. Body composition was assessed using hydrostatic weighting and total body water. After twelve weeks of training there were similar significant changes in body composition in both groups. Both groups experienced increases in fat free mass (low protein, 1kg; high protein, 1.8 kg), and decreases in fat mass (low protein, 1.7 kg; high protein 1.9 kg) and percentage body fat (low protein, 2.1%; high protein, 2.3%).

When assessing protein requirements for strength athletes while performing intensive training over a period of 30-days, researchers were also able to assess changes in skeletal muscle mass (Lemon et al., 1992). After determining the protein requirement to be 1.6-1.7g protein • kg^{-1} • day^{-1}, researchers indicated no significant changes to muscle mass. However, a longer period (> 30 days) of supplementation may be needed to detect muscle hypertrophy.

2.5 Whey Protein Supplementation and Resistance Training

Five studies have investigated the long-term effects of supplementing whey protein while resistance training. Demling and DeSanti (2000) investigated the effects of a moderate hypocaloric, high protein diet and resistance training, using two different protein supplements, versus a hypocaloric diet alone on body compositional changes in overweight police officers. The hypocaloric diet consisted of consuming 80% of the predicted daily calories needed for age, size and activity of each subject. After 12 weeks of treatment both groups who had consumed the protein supplements (whey or casein; protein totals of 1.5g • kg^{-1} • day^{-1}) experienced increases in lean mass (4 ±1.4 kg casein and 2 ±0.7 kg whey), whereas the non-protein group had gains of 0.4 ±0.4 kg. Others have also shown similar increases in lean body mass when combining a resistance training program with whey protein supplementation (Burke et al., 2001). After six weeks of high intensity resistance training while supplementing with whey protein (1.2g • kg^{-1} • day^{-1}), lean body mass, assessed by DEXA, was found to increase by 2.3kg, whereas the placebo group (1.2g maltodextrin • kg^{-1} • day^{-1}) had mean gains of 0.9kg of lean body mass. Mean strength increases in bench press and parallel squat increased in both the whey supplement and placebo groups by 6.3 kg and 7.2 kg and 22.5 kg and 21.5 kg, respectively.

Agin et al. (2001) investigated the effects of whey protein supplementation and resistance training in women with HIV. After completing a 14-week treatment period that implemented resistance training three days per week (3 sets of 10 exercises at 8-10 repetitions) and supplementing with whey protein powder ($1.0g \bullet kg^{-1} \bullet day^{-1}$), researchers revealed only slight changes in skeletal muscle mass. Compared to a resistance-training group who had mean significant muscle gains of 1.2 kg, the supplemented group had non-significant gains (0.6 kg) in skeletal muscle. The researchers of the study did not mention dietary intake values; therefore a possible cause for the results may be due to inadequate dietary intakes of the subjects in the whey protein supplemented group.

Colker et al., (2000) compared two protein supplements while resistance training over a ten week period using 16 athletic men as subjects. In addition to their dietary protein, that was not to exceed $1.6g \bullet kg$ of body $weight^{-1} \bullet day^{-1}$, one group ingested $40g \bullet day^{-1}$ of whey protein (n=8) while another group (n=8) ingested a combination of whey protein ($40g \bullet day^{-1}$), L-glutamine ($5g \bullet day^{-1}$), and branched chain amino acids ($3g \bullet day^{-1}$). Results of this study indicated that the addition of only $5g \bullet kg^{-1} \bullet day^{-1}$ of L-glutamine and $3g \bullet kg^{-1} \bullet day^{-1}$ of branch chain amino acids to the $40g \bullet day^{-1}$ of whey protein produced significant gains in fat-free mass of 1.57 kg and 0.49 kg, respectively and total body mass increases of 1.25 kg and -0.34 kg respectively, compared to the whey protein. The authors of this study did not indicate the training protocol used, when the supplement was ingested, what the supplement was ingested with or the total caloric and macronutrient amounts of each group.

Kreider et al. (2003) compared the effects of supplementing with whey protein fortified with either branched chain amino acids and L-glutamine or casein on body composition during ten weeks of resistance training. Subjects consumed either 40 grams of whey protein plus 8 grams of casein (WC), 40 grams of whey protein plus 3 grams of branched chain amino acids and 5 grams of L-glutamine (WBG) or 48 grams of a carbohydrate placebo (P). Results indicated that subjects who supplemented with whey protein fortified with 3 grams of branch chain amino acids and 5 grams of L-glutamine experienced similar changes in body mass as subjects who supplemented with isocaloric carbohydrate. However, subjects that supplemented with whey protein fortified with only 8 grams/day of casein protein experienced greater gains in total body mass than the two comparison groups (WC =1.9 ±0.7kg; WBG = 0.2 ±0.5kg; P = 0.2 ±0.4kg). Also of interest, those subjects who supplemented with the whey protein fortified with casein experienced greater gains in lean body mass than the two comparison groups (WC =1.8 ±0.6kg; WBG = 0.0 ±0.3kg; P = 0.1 ±0.3kg). To explain the results of this study, it was theorized that whey protein fortified with casein protein promoted a slower gastric release and/or promotes a more prolonged increase in amino acid levels providing a greater opportunity for an anabolic response.

2.6 Protein-Carbohydrate Supplementation

The effect of carbohydrate on post-exercise protein metabolism and muscle hypertrophy has received limited attention. It was recently shown that neither lipids nor carbohydrates stimulated muscle protein synthesis in the absence of amino acids (Svanberg et al., 1999). Tipton and Wolfe (2001) have suggested that the influence of carbohydrates on protein metabolism is through its indirect stimulation of insulin. Researchers have recently investigated the effect of carbohydrate supplementation on insulin concentration and protein metabolism after resistance training (Roy et al., 1997). Eight healthy active males (aged 20-25 yr) were supplemented with either carbohydrate ($1.0g \bullet kg^{-1}$) or placebo (Nutrasweet) after a bout of resistance exercise. Insulin levels were found to be elevated up to two-hours post exercise in the carbohydrate supplemented group while no elevations occurred in the placebo group. Also present in the carbohydrate group were decreased markers for muscle protein breakdown. Although net muscle protein balance was not assessed, if muscle protein breakdown was decreased after ingesting carbohydrate this could lead to a more positive or less negative protein balance after exercise, thus potentially resulting in a larger gain of muscle mass.

Biolo et al. (1999) using isotopic tracer and muscle biopsy techniques, investigated the interaction between the effects of insulin and exercise on the rates of muscle protein synthesis and breakdown, and amino acid transport in five male subjects (mean age 29 ±5 yrs). After infusion of insulin at rest and 3 hours after exercise, researchers found that hyperinsulinemia at rest increased muscle protein synthesis without affecting protein breakdown. Results also revealed that hyperinsulinemia after exercise blunted the exercise-mediated acceleration of protein breakdown. Chandler et al. (1994) assessed the effect of a carbohydrate, protein and carbohydrate-protein supplement on anabolic hormones after weight-training in nine male weight lifters. Subjects performed eight exercises with 2 sets of 8-10 repetitions at 75% of 1-RM and then consumed a supplement or placebo immediately and 2 hours post-exercise. It was found that the carbohydrate-protein treatments produced significantly higher insulin concentrations than the protein and placebo treatments alone, as well the protein treatment produced significantly higher insulin levels than that of the placebo. Significant elevations in growth hormone were also found at 5-6 hours post-exercise in the carbohydrate-protein treatment compared to all other treatments. Kraemer et al.(1998) showed ingestion of a protein-carbohydrate supplement before and after training over three consecutive days elicits hormonal changes that may be beneficial to resistance training individuals. In a cross over design nine resistance trained men consumed a supplement composed of 33% protein and 67% carbohydrate that provided 300 kcal, 25 grams of protein, and 50 grams of carbohydrate two hours prior and immediately post exercise. Exercise consisted of performing four sets of four exercises performed in the following order; squats, bent over row, bench press, and seated shoulder press separated with 2 minutes of rest between sets. Results indicated that ingestion of the protein-carbohydrate supplement resulted in higher concentrations of serum insulin and insulin growth factor (IGF-1) compared to a placebo supplement. Serum cortisol levels were found to be significantly lower after three consecutive days of supplementation.

Kreider et al. (1996) supplemented 26 resistance trained subjects for four weeks with either maltodextrine or a nonisocaloric commercially available carbohydrate-protein (Gainers Fuel®1000) or a commercially available carbohydrate-protein-creatine monohydrate (Phosphagain®) supplement designed to increase lean tissue accretion without excessive energy intake. Subjects in the maltodextrine group ingested 190g/day that was divided into three doses and consumed with morning, midday and evening meals. The subjects consuming the Gainers Fuel®1000 supplement ingested 290g of carbohydrate, 60g of protein, 1g of fat, as well as minerals and vitamins that provided an extra 1400 kcal per day to their diet. Subjects consuming the Phosphagain® supplement ingested 64g of carbohydrate, 67g of protein, 5g of fat, 5g of creatine monohydrate, as well as minerals and vitamins that provided an extra 570 kcal per day to their diet. Subjects were instructed to perform their regular resistance training routine through the duration of the study, therefore, training volume and exercises were not controlled. The number of participants in each group was unspecified. At the completion of the study, it was shown that those subjects consuming the maltodextrine and carbohydrate-protein had similar changes in body composition as measured by DEXA, however, the subjects consuming the creatine monohydrate supplement had greater increases in lean tissue mass (2017g) than those subjects in the carbohydrate-protein (665g) or maltodextrine (672g) group.

Meredith et al. (1992) revealed that when older men (61-72 years) consumed a carbohydrate-protein supplement (n = 6) (.33g protein • kg^{-1}, .89g carbohydrate • kg^{-1}) while resistance training the lower limbs, significant adaptations to left midthigh muscle area (mean = 14.5 cm^2) were seen compared to a group (n = 5) of unsupplemented participants (mean = 6 cm^2). Thigh adaptations were assessed by girth measures and CT scans. Subjects exercised the knee extensor and flexor muscles of both legs using a Universal "thigh-knee" machine. Three sets of eight repetitions (80% of 1-RM) for each muscle group were performed three times per week for twelve weeks. Measurement of body composition via hydrostatic weighing revealed that only the supplemented subjects had significant gains in muscle mass, however, both groups produced similar gains in muscular strength.

Tarnopolsky et al. (2001) tested the hypothesis that a post exercise protein-carbohydrate supplement (PRO-CH0) would result in similar increases in fat free mass, muscle fiber area and strength as compared with a post exercise creatine monohydrate-carbohydrate (CR-CHO) supplement during a two month resistance training program in untrained men. Nineteen untrained males (N=11; creatine monohydrate-carbohydrate, N=8; protein-carbohydrate) resistance trained 6 days per week for 8 weeks in a supervised setting. The protein-carbohydrate supplement consisted of 10g of caseinate and 75g of dextrose (~340 kcal). The creatine monohydrate-carbohydrate supplement (CELL-Tech®) consisted of 10g creatine monohydrate, 75g dextrose, 2g taurine, 250mg ascorbic acid, 300ug chromium picolinate, 200mg α-lipoic acid, 100mg phosphorus, 150 mg potassium, 60 mg sodium, 70mg magnesium, and 20mg calcium (~308 kcal). Each daily supplement dose was consumed within 30 minutes of completion of the resistance training routine. Following the 8 week intervention period both groups had significant changes in total body mass (CR-CHO; 5.4%, PRO-CHO; 2.4%), fat free / bone free mass (CR-CHO; 6.4%, PRO-CHO; 4.1%), type I fiber area (CR-CHO; 21.8 $\pm$11.2 %, PRO-CHO; 17.4 $\pm$18.7 %), type II fiber area (CR-CHO; 25.0 $\pm$20.4%, PRO-CHO; 26.5 $\pm$25.7), as well as similar significant increases in 1-RM strength measures.

Rozenek et al. (2002) compared two groups of novice male weight trainees that supplemented with either an isocaloric carbohydrate (n = 25) or a protein and carbohydrate mixture (n = 26) against a control unsupplemented group (n = 21) on their abilities to alter body composition and muscular strength while concurrently performing eight weeks of resistance training. The protein–carbohydrate supplement was consumed with three cups of two-percent milk that provided an extra 106g of protein and 356g of carbohydrate per day. The carbohydrate supplement was also consumed with three cups of two-percent milk and provided an extra 24g of protein and 450g of carbohydrate per day. Each subject completed a whole body resistance training program 4 days per week for eight weeks. Compared to the control group who performed the same training program with no supplement, results showed no significant difference in strength measures between the three groups, however, significant increases were seen in total body mass (3.1 ±3.1 kg and 3.1 ±2.2 kg) and in fat free mass (2.9 ±3.4 kg and 3.4 ±2.5 kg) in the protein-carbohydrate and carbohydrate group respectively. The control group showed no significant increases in total body mass or fat free mass. No significant differences existed between the three groups with regards to total energy, protein, carbohydrate and fat consumption. Addition of the supplements resulted in significantly higher energy intakes for the protein-carbohydrate (18.2 ±3.8 Mj • day^{-1}) and carbohydrate group (18.2 ±3.5 Mj • day^{-1}) compared to the unsupplemented control group (10.9 ±3.5 Mj • day^{-1}). Researchers of this study concluded that high-calorie supplements are effective in increasing body mass and fat free mass when combined with resistance training. As well, the researchers supported the concept that once individual protein requirements are met, the total energy intake may be the most important dietary factor related to body composition changes rather than the specific ingredients used to provide additional energy.

2.7 Timing of Supplementation

The timing of supplement ingestion has recently been a topic of interest to researchers. Esmarck et al. (2001) investigated the importance of the timing of protein-carbohydrate (10g protein, 7g carbohydrate) intake after exercise on the development of muscle hypertrophy in 13 elderly untrained men (mean age 74 yrs). A progressive resistance exercise program was performed 3 times per week for 12 weeks. Three exercises were performed; leg press, latissimus dorsi pulldown and knee extension with sets and reps ranging from 3-5 and 8-20, respectively. Subjects (matched for body composition and daily protein intake) either consumed the supplement (n = 7) immediately after training (P0) or two hours after training (P2) (n = 6). Lean body mass assessed by DEXA, increased by 1.8 ±0.7% in P0 and decreased by 1.5 ±0.7% in P2. Cross sectional area, assessed by magnetic resonance scanning of the quadriceps increased from 54.6 ±0.5 cm^2 to 58.3 ±0.5cm^2 in P0, whereas no significant change occurred in P2. Mean fiber area increased (4047 ±320 to 5019 ±615 um^2) in the P0 group, with no significant changes in the P2 group. Dynamic 5-RM and isokinetic strength in the P0 group increased by 46 and 15%, respectively, whereas P2 only improved in dynamic strength by 36%. Even though no control group was present in the study, the researchers concluded that intake of a protein – carbohydrate supplement immediately after training is important for the development of muscle hypertrophy in elderly men in response to resistance training.

When investigating the effect of ingesting an oral essential amino acid-carbohydrate supplement on muscle protein, Rasmussen et al. (2000) have also revealed positive benefits for increases in muscle mass. Six subjects (3 men, 3 women) randomly consumed a supplement consisting of 6g of essential amino acids and 35g of sucrose or a placebo at 1 hour and 3 hours after a bout of intensive resistance exercise. The researchers revealed via isotopic tracer methology that net muscle protein synthesis was significantly increased above baseline levels when the supplement was consumed at 1 hour and 3 hours after exercise with no statistical difference existing between the treatment times. Contrary to other studies that have shown decreases in protein breakdown when being supplemented with carbohydrate, this study revealed that protein breakdown did not significantly change regardless of when the supplement or placebo were consumed. The same researchers in a later study (Tipton et al., 2001) investigated whether consuming an oral amino acid-carbohydrate supplement before exercise would result in a greater stimulus for increased muscle protein synthesis than supplementation after exercise. Using isotopic tracer and muscle biopsy techniques as in their earlier study, these researchers revealed that ingestion of the oral amino acid-carbohydrate supplement immediately before exercise was more beneficial for increases in muscle protein synthesis. During exercise, amino acid delivery to the muscle was greater for the pre-exercise supplement group (1,890 ±396 nmol • min^{-1} •100 ml • leg volume) than the post-exercise supplement group (654 ±80 nmol • min^{-1} •100 ml • leg volume). At 1 and 2 hours post exercise amino acid delivery was also greater in the pre-exercise supplement group (828 ±129 nmol • min^{-1} • 100 ml • leg volume (1hr), and 539 ±80 nmol • min^{-1} • 100 ml • leg volume (2hr)) than the post-exercise supplement group (506 ±97 nmol • min^{-1} •100 ml • leg volume (1hr), and 341 ±59 nmol • min^{-1} • 100 ml • leg volume (2hr)). Results also indicated that blood flow to the working muscles was significantly elevated during exercise in both groups. However, the pre-supplement group had significantly greater blood flow values than the non-supplemented group during the first hour after exercise. The researchers concluded that the combination of increased amino acid levels at a time when blood flow is increased appears to offer the maximum stimulation of muscle protein synthesis by increasing amino acid delivery to the muscle and thus amino acid availability for protein synthesis.

2.8 Conclusion

Resistance training increases both protein synthesis and breakdown. Studies have shown that if individuals remain in a fasted state post exercise, protein breakdown is greater than protein synthesis, resulting in a negative net protein balance. Studies have also demonstrated a shift from a negative to a positive net protein balance if amino acids are ingested immediately pre and/or post exercise. In addition, if a mixture of amino acids and carbohydrate is ingested a greater net positive protein balance results. As well, initial work investigating acute hormonal responses to resistance training have revealed greater anabolic effects of ingesting a supplement containing protein and/or carbohydrate immediately pre and post a resistance training bout. Initial studies have indicated some benefits of supplementing with whey protein while resistance training, however, there is some research showing similar increases in muscle mass and strength when ingesting carbohydrate or an isocaloric mixture of whey protein and carbohydrate. Research has revealed the effects of ingesting a mixture of carbohydrate and protein, however, there is no information on the effects of ingesting a mixture of carbohydrate and whey isolate protein. Information is needed that will aid our understanding on the effects of supplementing with a mixture of whey isolate protein and carbohydrate on body composition and strength performance while resistance training.

CHAPTER 3

Research Methods

3.1 Research Design

A treatment-control double blind experimental design was used to make comparisons between subjects receiving a treatment that consisted of a mixture of whey protein isolate (*Protient., ST. Paul, Minnesota*) and carbohydrate; (ProCarb) versus a carbohydrate (Carb) (Maltodextrine). Prior to being randomly placed into either of the study groups, all measurements (1-RM strength, body composition, macronutrient and total energy intake) were performed at baseline. Baseline 1-RM strength and total lean body mass values were added together for each subject and used for ranking the subjects from highest to lowest. After ranking, subjects were randomly assigned to one of the experimental groups by a person not associated with any other aspect of the study. Once assigned to either the ProCarb group or Carb group the subjects then participated in an 8-week high-intensity resistance training routine. The major variables assessed both before and after the 8-week training study were body composition (total body mass, lean body mass, fat mass and body fat percentage) and muscular strength. A timeline of the study protocol can be seen on Figure A (Appendix A).

3.2 Participants

After gaining approval from the Faculty of Physical Education and Recreation's Faculty Ethics Review Board (Appendix B), twenty-five experienced university male weight trainers (age 18-25) were recruited from the University of Alberta's general student population through poster advertisements that were placed throughout the university campus. After signing a letter of informed consent, participants were screened for good health. Criteria for participation included being active in a resistance training program, an average of three days per week for three months prior to the beginning of the study and no previous use of protein and/or carbohydrate supplements. An example of the poster advertisement and ethics approval letter can be seen in Appendix B.

3.3 Resistance Training Program

A high-intensity, whole-body eight week resistance training program was performed by the participants at the University of Alberta's Fitness and Lifestyle Center. The subjects were supervised by either the main investigator or by other trained student supervisors in the Faculty of Physical Education and Recreation. Each training session began with a five-minute warm up on either a treadmill or cycle ergometer followed by light static stretching exercises. All subjects performed the same 4-day per week split routine that progressed in a linear fashion. Day 1 involved training the chest, shoulders and back musculature and included, in order, the following exercises: bench press, incline bench press, dumbbell row, latissimus pull-downs, military press, and upright rowing. Day 2 involved training the legs and arms and included, in order, the following exercises: leg squat, incline (45°) leg press, leg curls, knee extension, biceps preacher curls and triceps extension. A typical training week featured day 1 and 2 on Monday and Tuesday, respectively, followed by a recovery day on Wednesday. Day 1 and 2 was then repeated on Thursday and Friday, followed by a 2-day recovery period on Saturday and Sunday. All exercise intensities were periodized to gradually increase over the course of the 8-week program (Baechle and Earle, 2000)

During week one and week two, subjects performed three sets of ten-to-twelve repetitions for each exercise. At the start of week one, resistance was set at 75% of a pre-determined 1-RM and if needed the weight was adjusted so that subjects attained muscular failure at the twelfth repetition. Week three to week five subjects performed four sets of ten-to-twelve repetitions for each exercise. Week six to week eight, subjects increase the resistance and perform four sets of eight-to-ten repetitions of each exercise.

3.4 Supplementation Protocol

The ProCarb group received 1.64g • kg^{-1}• day^{-1} of a whey protein isolate-carbohydrate supplement (~ 33% protein, 67% carbohydrate (Kraemer et al., 1998)). The ProCarb supplement contained minimal cocoa and low calorie sweetener to increase satiety of the supplement. The ProCarb supplement was designed to provide the subjects in the ProCarb group with an additional 0.5g of protein • kg body $mass^{-1}$ • day^{-1}. The ProCarb supplement provided an additional 6.5 kcal • kg body $mass^{-1}$ • day^{-1}. If needed subjects were counseled on how to ingested approximately 1.5g of protein • kg body $mass^{-1}$ • day^{-1} in their diet. Therefore, subjects in the ProCarb group were to ingest 2g of protein • kg body $mass^{-1}$ • day^{-1} when the ProCarb supplement was consumed. The Carb group consumed an isoenergenic carbohydrate supplement that was similar in taste, texture and calories to that of the ProCarb group. Nutritional information and the amino acid profile for the whey isolate protein are presented in Appendix C. All supplements were be pre-measured, packaged in airtight plastic bags and distributed in a double-blinded manner. Subjects received instructions on measuring and mixing of all supplements that were consumed with water. Supplements were consumed in 3 equal portions during the day with each portion being mixed in ~400ml of water. One of the equal portions was consumed immediately before resistance training, a second equal portion within thirty minutes after resistance training and the third equal portion consumed ad libitium some time after the second portion. Subjects were instructed to consume no other foods within 1 hour before or after the consumption of the supplement. The ingestion of supplements immediately prior to and following exercise was implemented because muscle protein synthesis has been shown to increase and protein degradation decrease if consumption of amino acids or carbohydrate has occurred prior to exercise (Roy et al., 1997; Tipton et al., 2001) or consumed one hour following exercise (Esmarck et al., 2001; Rasmusen et al., 2000; Roy et al., 1997). On non-training days subjects consumed their usual diet with no supplementation.

3.5 Measurements

Body composition measures were assessed before and after training with use of dual energy x-ray absoptiometry (General Electric, Lunar Prodigy). The same technician performed all pre and post intervention DEXA scans. Scan accuracy was assessed by analyzing a phantom spine. To reduce measurement error and increase reliability of measure, the same technician performed daily calibrations prior to all scans using a calibration block that was provided by the machine manufacture. DEXA has previously been shown to be a reliable measure for bone mineral and soft tissue composition (Mazes et al., 1990).

To determine total daily energy and macronutrient content, a dietary analysis for each subject was performed at baseline and during the third and eighth week of intervention utilizing a nutritional software program (Food Processor, ESHA Research Salem, OR). Subjects recorded a consecutive three-day food record that included one weekend day on every occasion.

Strength assessments were performed at baseline and post intervention with modification of a previously used technique (Baechle and Earle, 2000)). Subjects warmed-up by riding a cycle ergometer for five minutes and then performed two sets of 10 push-ups separated by one-minute of rest. Stretching exercises were performed for the chest (static stretch held against a wall), arms (static tricep stretch) and legs (modified hurdler's stretch). Subjects were instructed on the correct technique for bench press and the incline leg press. Leg press lifts were standardized by having the subjects lower the leg press to 90° flexion of the knee joint; at 90° flexion subject were provided a cue to extend the leg. Bench press was standardized by having subjects position their hands on the bar that resulted in 90° flexion of the elbow joint when the barbell was position 5cm over the chest. Each subject then performed ten repetitions of a weight estimated to be 50% of their 1-RM. On every bench press lift a five point lifting technique was employed where the head, shoulders and gluts remained positioned on the bench and the feet remained positioned on the floor. After a three minute recovery period each subject performed three repetitions of a weight estimated to be 75% of their 1-RM. Each subsequent attempt was a single lift to determine the subjects 1-RM. If a successful attempt was made, further weight was added (2-5 Kg) and successive lifts occurred until failure. Each lift was separated by a three-minute recovery period. The average total number of sets performed to determine 1-RM measures was 5 sets.

3.6 Data Analysis

A two (ProCarb and Carb) x two (repeated measures) analysis of variance (ANOVA) was used for analysis of body composition and muscular strength variables. A two (ProCarb and Carb) x three (repeated measures) analysis of variance (ANOVA) was used for analysis of energy and macronutrient intake. Newman-Keuls post-hoc analysis was performed if significant "F" ratios were produced. All data presented are means ±SD unless otherwise noted. Significance was set at an alpha level (p) of 0.05 for all statistical tests.

CHAPTER 4

Results

4.1 Subject Characteristics

Mean age, height and weight of the subjects in the ProCarb group were 20.7 ±2.1 years, 179.4 ±7.3 cm and 75.8 ±12.0 kg, respectively. The Carb groups mean age, height and weight were 21.6 ±2.1 years, 177.7 ±8.0 cm and 75.1 ±10.1 kg, respectively. There was no significant difference between the two experimental groups in the preceding measures.

4.2 Body Composition

At baseline there was no significant difference between the groups for any physical characteristics. Total body mass increased significantly from baseline to post training in both groups (ProCarb, 1.0 ±1.2kg; Carb 1.1 ±1.1kg), with no significant difference between the groups (Table 4.2.1). Group baseline and post training values for body composition measures assessed by DEXA are given in Table 4.2.2. and Table 4.2.3 All pre-post body composition values for each individual participant are given in Appendix E. No statistically significant differences existed between the groups in any of the body composition measures at baseline or post training. Significant increases from baseline occurred in both groups for total lean body mass (ProCarb, 1326.3 ±944.8g; Carb, 1431.7 ±944.8g), leg lean tissue mass (ProCarb, 678.0 ±638.2g; Carb, 503.2 ±621.2g), arm lean tissue mass (ProCarb, 464.9 ±424.6g; Carb, 496.9 ±305.5g), and upper body lean tissue mass (ProCarb, 615.5 ±779.7g; Carb, 922.1 ±990.5g). Fat mass, body fat percentage, and trunk lean tissue mass did not change from baseline to post training.

Table 4.2.1 Body mass measures for protein-carbohydrate (ProCarb) and carbohydrate (Carb) groups at baseline (BL), post training (PT), and total change.

	Time Periods		
Body Mass (kg)	**BL**	**PT**	**Change**
ProCarb (n = 12)	75.8 ±12.0	76.9 ±11.8*	1.0 ±1.2
Carb (n = 13)	75.1 ±10.1	76.2 ±10.3*	1.1 ±1.6

Body mass values represented are in kilograms (kg), BL = baseline, PT = post training, Change = PT – BL. *Significantly ($p < 0.05$) different from baseline.

Table 4.2.2 Body composition characteristics for protein-carbohydrate (ProCarb) and carbohydrate (Carb) groups at baseline (BL), post training (PT), and total change.

	Time Periods		
Characteristic	**BL**	**PT**	**Change**
Body Mass (g)			
ProCarb (n = 12)	75.9	77.0*	1.1
S.D.	*±12.0*	*±11.7*	*±1.1*
Carb (n=13)	74.9	76.2*	1.4
S.D.	*±10.2*	*±10.3*	*±1.5*
Lean Body Mass (g)			
ProCarb (n=12)	62032.2	63358.4*	1326.3
S.D.	*±7022.4*	*±7181.3*	*±944.8*
Carb (n=13)	59403.3	60835.0*	14317.7
S.D.	*±8231.6*	*±8561.9*	*±1283.3*
Fat Mass (g)			
ProCarb (n = 12)	10579.5	10332.1	-247.4
S.D.	*±6012.4*	*±6000.6*	*±947.6*
Carb (n=13)	12230.3	12203.2	-27.2
S.D.	*±5042.2*	*±5270.5*	*±1224.5*
Body Fat %			
ProCarb (n=12)	14.0	13.5	-0.5
S.D.	*±5.3*	*±5.4*	*±1.2*
Carb (n=13)	16.8	16.5	-0.4
S.D.	*±6.1*	*±6.4*	*±1.7*
Total Bone Mineral Content (g)			
ProCarb (n = 12)	3318.7	3312.6	-6.1
S.D.	±440.4	±430.3	±40.1
Carb (n=13)	3216.5	3224.4	7.8
S.D.	±568.9	±547.9	±47.3

Values represented are from total body DEXA (G.E. Lunar Prodigy) scans, BL = baseline, PT = post training, Change = PT – BL. *Significantly ($p<0.05$) different from baseline.

Table 4.2.3 Body section composition characteristics for protein-carbohydrate (ProCarb) and carbohydrate (Carb) groups at baseline (BL), post training (PT), and total change.

Characteristic	Time Periods BL	PT	Change
Trunk Lean Tissue Mass (g)			
ProCarb (n = 12)	28626.8	28777.3	150.6
S.D.	*±2880.2*	*±3065.4*	*±1021.9*
Carb (n=13)	27381.9	27807.1	425.2
S.D.	*±4358.3*	*±4202.0*	*±994.2*
Leg Lean Tissue Mass (g) Left and Right Totals			
ProCarb (n=12)	21045.8	21723.8*	678.0
S.D.	*±2752.1*	*±2937.0*	*±638.2*
Carb (n=13)	20190.7	20693.9*	503.2
S.D.	*±2551.0*	*±2981.6*	*±621.2*
Arm Lean Tissue Mass (g) Left and Right Totals			
ProCarb (n=12)	8185.3	8650.2*	464.9
S.D.	*±1530.1*	*±1250.2*	*±426.6*
Carb (n=13)	7724.2	8221.2*	496.9
S.D.	*±1383.9*	*±1387.0*	*±305.5*
Upper Body Lean Tissue Mass (g) Trunk and Arm			
ProCarb (n=12)	36812.0	37427.5*	615.5
S.D.	*±4240.6*	*±4261.7*	*±779.7*
Carb (n=13)	35106.2	36028.2*	922.1
S.D.	*±5561.9*	*±5504.7*	*±990.5*

Values represented are from total body DEXA scans (G.E. Lunar Prodigy), BL = baseline, PT = post training, Change = PT – BL *Significantly ($p<0.05$) different from baseline.

4.3 Muscular Strength

At baseline there were no significant differences in bench press or leg press strength (Table 4.3.1). Muscular strength for 1-RM bench press increased significantly (ProCarb, 5.7 ±5.9kg; Carb, 5.0 ±3.4kg) as did 1-RM leg press (ProCarb, 50.6 ±30.0kg; Carb, 42.8 ±25.0kg) from baseline to post training in both groups, however, there was no difference between the groups. All individual pre-post strength values for 1-RM bench press and leg press are presented in Appendix F. Compliance of the training sessions was 93 and 96% for the ProCarb and Carb group respectively.

Table 4.3.1 Bench press and leg press 1-RM strength values for baseline (BL), post training (PT), and total change.

	Bench Press 1-RM (kg)		
	BL	**PT**	**Change**
ProCarb(n=12)	87.7	93.3*	5.7
S.D.	± 18.6	± 16.8	± 5.9
Carb (n=13)	83.5	88.5*	5.0
S.D.	± 18.5	± 17.2	± 3.4

	Leg Press 1-RM (kg)		
	BL	**PT**	**Change**
ProCarb(n=12)	256.5	307.0*	50.6
S.D.	± 61.2	± 64.4	± 30.0
Carb (n=13)	243.2	286.1*	42.8
S.D.	± 40.9	± 52.8	± 25.0

Values represented are in kilograms (kg) pressed, 1-RM = Maximum load pressed in one repetition, BL = baseline, PT = post training, Change = PT –BL. *Significantly ($p<0.05$) different from baseline.

4.4 Diet

Dietary caloric and macronutrient intake of individual participants reported via the 3-day dietary logs for the protein-carbohydrate and carbohydrate groups at baseline, week three and week eight are given in Appendix D. No other supplements were consumed during the intervention period. As well, no side effects were reported as a result of ingesting the supplements. At baseline analysis of three-day dietary records indicated a significantly higher amount of energy (ProCarb, 2881 ±754 Kcal; Carb 2339 ±521 Kcal), carbohydrate (ProCarb, 407 ±109g; Carb, 296 ±58g) and fat (ProCarb, 101 ±29g; Carb, 78 ±27g) consumed in the ProCarb group (Table 4.4.1). There was no significant difference in the absolute and relative amounts of consumed protein. Analysis of energy and macronutrient intake from habitual diet at week-3 revealed significantly higher amounts of calories (ProCarb, 2695 ±682kcal; Carb, 2300 ±424Kcal), carbohydrate (ProCarb, 352 ±135g; Carb, 282 ±85g) and fat (ProCarb, 106 ±41g; Carb, 79 ±14g) being consumed in the ProCarb group (Table 4.4.1). Analysis of energy and macronutrient intake from habitual diet at week-8 revealed significantly higher amounts of calories (ProCarb, 2845 ±687kcal; Carb, 2475 ±447Kcal), and carbohydrate (ProCarb, 350 ±116g; Carb, 296 ±61g) being consumed in the ProCarb group (Table 4.4.1). Addition of the supplements resulted in significantly higher absolute (ProCarb, 156 ±33g; Carb, 106 ±32g) and relative (ProCarb, 2.1 ±0.5g; Carb, 1.5 ±0.5g) amounts of protein intake in the ProCarb group with non-significant differences in all other macronutrient and caloric totals at week three (Table 4.4.2). Ingestion of the supplement and habitual diet at week-8 resulted in significantly higher absolute (ProCarb, 159 ±38g; Carb, 120 ±38g) and relative (ProCarb, 2.1 ±0.4g; Carb, 1.6 ±0.7g) amounts of protein in the

ProCarb group with non-significant differences in all other macronutrient and caloric totals (Table 4.4.2). Table 4.4.3 indicates the percentage of energy that each macronutrient supplied to the total energy consumed in the ProCarb and Carb group.

Table 4.4.1 Energy and macronutrient 3-day dietary intake for habitual and counselled diets for protein-carbohydrate (ProCarb) and carbohydrate (Carb) groups at baseline (BL), week 3(WK3), and week 8 (WK8).

Energy / Macronutrient	Time Periods		
	BL	WK3	WK8
Energy (kcal)			
ProCarb (n = 12)	2881*	2695*	2845*
S.D.	*±754*	*±682*	*±687*
Carb (n=13)	2339	2300	2475
S.D.	*±521*	*±424*	*±447*
Protein (g)			
ProCarb (n = 12)	110	118	120
S.D.	*±26*	*±33*	*±35*
Carb (n=13)	112	106	119
S.D.	*±32*	*±32*	*±38*
Carbohydrate (g)			
ProCarb (n=12)	407*	352*	350*
S.D.	*±109*	*±135*	*±116*
Carb (n=13)	296	282	296
S.D.	*±58*	*±85*	*±61*
Fat (g)			
ProCarb (n = 12)	101*	106*	110
S.D.	*±29*	*±41*	*±35*
Carb (n=13)	78	79	81
S.D.	*±27*	*±14*	*±29*
Protein (g/kg)			
ProCarb (n=12)	1.5	1.6	1.6
S.D.	*±0.4*	*±0.4*	*±0.4*
Carb (n=13)	1.5	1.5	1.6
S.D.	*±0.5*	*±0.5*	*±0.7*

*Significantly ($p<0.05$) different from carbohydrate group. WK3 and WK8 are counselled diets.

Table 4.4.2 Absolute and relative energy and macronutrient intakes from diet and supplement consumption for protein-carbohydrate (ProCarb) and carbohydrate (Carb)groups at week 3 (WK3), and week 8 (WK8).

Energy / Macronutrient	Time Periods	
	WK3	WK8
Energy (kcal)		
ProCarb (n = 12)	3155	3308
S.D.	*±685*	*±722*
Carb (n=13)	2759	2936
S.D.	*±453*	*±472*
Energy (kcal) / kg		
ProCarb (n = 12)	42	43
S.D.	*±9*	*±8*
Carb (n=13)	36	39
S.D.	*±6*	*±6*
Carbohydrate (g)		
ProCarb (n=12)	435	433
S.D.	*±137*	*±124*
Carb (n=13)	397	411
S.D.	*±123*	*±63*
Carbohydrate (g/kg)		
ProCarb (n = 12)	5.7	5.6
S.D.	*±1.9*	*±1.3*
Carb (n=13)	5.2	5.4
S.D.	*±1.6*	*±1.1*
Protein (g)		
ProCarb (n=12)	156*	159*
S.D.	*±33*	*±38*
Carb (n=13)	106	120
S.D.	*±32*	*±38*
Protein (g/kg)		
ProCarb (n=12)	2.1*	2.1*
S.D.	*±0.5*	*±0.4*
Carb (n=13)	1.5	1.6
S.D.	*±0.5*	*±0.7*

*Significantly ($p<0.05$) different from carbohydrate group.

Table 4.4.3 Macronutrient energy percentage for 3-day dietary intake for habitual and counselled diets for protein-carbohydrate (ProCarb) and carbohydrate (Carb) groups at baseline (BL), week 3(WK3), and week 8 (WK8).

Energy / Macronutrient	Time Periods		
	BL	WK3	WK8
Protein %			
ProCarb (n = 12)	15.7	17.7	17.0
S.D.	*±1.0*	*±1.0*	*±1.0*
Carb (n=13)	19.0	18.1	19.6
S.D.	*±0.8*	*±1.0*	*±1.9*
Carbohydrate %			
ProCarb (n=12)	60.1	55.4	49.3
S.D.	*±3.2*	*±2.1*	*±3.4*
Carb (n=13)	50.6	51.7	48.3
S.D.	*±1.6*	*±2.1*	*±2.8*
Fat %			
ProCarb (n = 12)	31.4	35.7	35.0
S.D.	*±1.1*	*±1.7*	*±2.1*
Carb (n=13)	29.1	31.6	29.4
S.D.	*±1.9*	*±1.7*	*±2.4*

CHAPTER 5

General Discussion and Conclusions

5.1 Discussion

The findings of this study do not support the hypothesis that individuals supplementing with whey isolate protein and carbohydrate while resistance training will have greater increases in muscle mass and strength than those trainees supplementing with an isocaloric carbohydrate. This study revealed similar changes in body mass, body composition and strength measures while resistance training and supplementing with an isocaloric whey isolate protein-carbohydrate or carbohydrate supplement over an eight-week period. Both the whey isolate protein-carbohydrate and the carbohydrate group experienced similar increases in total body mass, lean tissue mass, leg lean tissue mass, arm lean tissue mass and total upper body lean tissue mass. As well, both groups had similar significant increases in bench press and leg press 1-RM strength. These findings are in agreement with a previous study that compared isocaloric protein-carbohydrate or carbohydrate supplementation while resistance training over a multi week period (Rozenek et al. 2002). The results are also in agreement with Kreider et al (1996) who revealed that ingestion of either a high calorie carbohydrate supplement or a high calorie protein-carbohydrate supplement (Gainers Fuel® 1000) were equally effective in promoting lean body mass while resistance training over a multi week period. As well, these findings are in partial agreement with Burke et al. (2001) who compared isocaloric supplementation of whey protein-creatine monohydrate, whey protein or maltodextrine combined with resistance training over a six week period.

Rozenek et al. (2002) observed significant increases in body mass, fat free mass and 1-RM strength measures in a protein-carbohydrate and a carbohydrate group compared to a non-supplemented control group. The habitual energy and nutrient intakes of the protein-carbohydrate and carbohydrate group subjects in the Rozenek et al. (2002) study were similar to our protein-carbohydrate and carbohydrate group values. The energy intake of the protein-carbohydrate subjects in the Rozenek et al. study were 2366, and 2427 Kcal at weeks 4, and 8 and 2524, and 2327 Kcal in the carbohydrate group at weeks 4, and 8 respectively. The total average energy intake of the unsupplemented control group in the Rozenek et al. study was 2597 Kcal • day^{-1}. The protein-carbohydrate group in the present study reported caloric intakes of 2695 and 2845 Kcal at week 3, and week 8, and the carbohydrate group reported caloric intake values of 2300 and 2475 Kcal at week 3, and week 8. However, addition of the supplement in the Rozenek et al. study provided higher total energy intakes in both the protein-carbohydrate (4348 ±902.0 Kcal • day^{-1}) and carbohydrate (4339 ±800 Kcal • day^{-1}) groups compared to the total energy ingested in protein-carbohydrate (3232 ±703 Kcal • day^{-1}) and carbohydrate (2848 ±463 Kcal • day^{-1}) groups in the present study. Also in comparison, the average total intakes of carbohydrate in the aforementioned study were higher [protein-carbohydrate (625 ±85g • day^{-1}) and carbohydrate (758 ±82g • day^{-1}) group] than the total average values ingested by the subjects in the present study [protein-carbohydrate (434 ±131g • day^{-1}); carbohydrate (404 ±93g • day^{-1})]. Average total protein intakes for the present study (ProCarb, 2.1 ±0.5g • kg^{-1} • day^{-1}; Carb, 1.6 ±0.6g • kg^{-1} • day^{-1}) and that of the Rozenek et al. study (protein-carbohydrate, 3.0 ±0.9g • kg^{-1} • day^{-1}; carbohydrate, 1.7 ±0.6g • kg^{-1} • day^{-1}) both met and exceeded the recommended amounts of dietary protein for resistance training individuals. Although the protein-carbohydrate and carbohydrate groups in the current and Rozenek et al. study experienced significant gains in lean tissue mass, the supplemented subjects in the Rozenek et al. study experienced larger total increases in lean tissue (protein-carbohydrate, 2.9 ±3.4 kg; carbohydrate, 3.4 ±2.5 kg; control, 1.4 ±1.7 kg) than those found in the current study (protein-carbohydrate, 1.3 ±0.9 kg; carbohydrate, 1.4 ±0.9 kg). Weight training experience of the subjects could account for the difference in lean tissue gains between both studies. Rozenek et al. used beginner weight trainers where as the present study used subjects who previously trained for a minimum of 3 months. Energy availability may also account for the differences in lean tissue mass between studies.

Previously, it has been recommended as a general guideline, that male athletes should consume at least 50 kcal • kg^{-1} • day^{-1} when training for 90 minutes (Economos et al., 1993). Other sources suggest that weight training athletes should consume 5 to 7g of carbohydrate per kilogram of body weight per day (Antonio, J. and Stout, R.S., 2001). Averaged over the training period, the subjects in the current study ingested the minimum recommended amounts of carbohydrate (Procarb, 5.7 ±1.6g • kg^{-1}; Carb, 5.3 ±1.4g • kg^{-1}), however, the recommended amounts of energy were not met (ProCab, 42 ±9 kcal • kg^{-1}; Carb, 38 ±6 kcal • kg^{-1}). Supplemented subjects in the Rozenek et al. study consumed the recommended amount of calories, with both groups averaging approximately

57 kcal • kg^{-1} • day^{-1}, however the unsupplemented group consumed approximately 33 kcal • kg^{-1} • day^{-1}. As well, both supplemented groups ingested the recommended amount

of carbohydrate (protein-carbohydrate, 8g • kg^{-1} • day^{-1}; carbohydrate, 10g • kg^{-1} • day^{-1}) were as the unsupplemented group ingested approximately 4g • kg^{-1} • day^{-1}.

The present results tend to support the suggestion of Rozenek et al. and the recommendations of Economos et al. and Batheja et al. that once the recommended amounts of dietary protein are met, the most important dietary component affecting changes in body composition while resistance training is total energy intake. In support of the previous suggestions and recommendations, Bohe et al. (2001) have indicated that muscle protein synthesis will not increase with higher available amounts of amino acids, and that a inhibitory feedback mechanism may be present once a specific amount of amino acids are supplied.

Tools utilized for measurement of body composition may also account for the differences seen in lean tissue mass gains in the present study and that of Rozenek et al.. DEXA (General Electric, Lunar Prodigy) was utilized in the present study and hydrostatic weighing was use in that of the Rozenek et al. study. In a heterogenous age group of adults measurement errors of two percent have been shown to exist between DEXA and hydrostatic weighing measurements (Heymsfield et al., 1991).

The present findings of significant increases in strength with no differences between groups are in agreement with Burke et al. (2001) who supplemented one group with whey protein and one group with an isocaloric maltodextrine. However, the findings do not support those of Burke and co-workers where the results suggest that supplementation of whey protein while resistance training resulted in significant increases in lean tissue with no increase in lean tissue occuring in subjects consuming an isocaloric carbohydrate supplement. Burke et al. indicated no differences between groups in dietary nutrient and caloric intake for the six week intervention period. Dietary protein and carbohydrate intake for the whey protein and carbohydrate group were 2.1 ±0.3g • kg^{-1}, 4.1 ±0.3g • kg^{-1} and 1.2 ±0.2g • kg^{-1} and 3.9 ±0.3g • kg^{-1}, respectively. Therefore, the amount of carbohydrate ingested by the whey protein group was below the previously cited recommended amounts and the amount of protein ingested by the carbohydrate group was below the recommended amounts for weight training individuals. The addition of the whey protein (1.2g • kg^{-1} • day^{-1}) and carbohydrate (1.2g • kg^{-1} • day^{-1}) supplement would have provided the whey protein group with 3.3g of protein • kg^{-1} • day^{-1}, thus exceeding the recommended amount of protein by 1.5g , while the carbohydrate group would have consumed a total of 5.1g of carbohydrate • kg^{-1} • day^{-1}.

As previously mentioned the findings of this study demonstrated similar change in body composition characteristics in both groups (Table 4.2.2). As there were no change in fat mass, it is assumed that the extra calories consumed, via the supplement, were expended during the high volume of weight training.

Timing of supplementation in the present and previously mentioned studies has not been uniform. The present study is the only known research to implement ingestion of a supplement immediately prior to training followed by two separate doses after each training session. The ingestion of supplements immediately prior to and following exercise was implemented because muscle protein synthesis has been shown to increase and protein degradation decrease if consumption of amino acids or carbohydrate has occurred prior to exercise (Roy et al., 1997; Tipton et al., 2001), or consumed one hour following exercise (Esmarck et al., 2001; Rasmusen et al., 2000; Roy et al., 1997). However, the Burke et al. and Rozenek et al. studies divided the daily dose of supplement into four and three portions throughout the day, respectively. Hence, supplementation immediately prior to and after training may not be needed for optimal protein accretion to occur.

It must be recognized that the studies investigating the effect of protein and carbohydrate ingestion have occurred in conditions not usually practiced by resistance training athletes. Subjects in most metabolic studies are in fasted states (12 hrs.) while very few athletes go with out food for more that a 3-4 hours. Therefore, the protein synthesis response to resistance training while in a fed state may not mirror that seen in seen in acute studies. Hence, if ingestion of protein and carbohydrate has occurred by means of food or supplementation prior to training, a sufficient amount of amino acids and glucose may be present to elicit a state of net protein anabolism. Tiption et al. (2001) compared the anabolic response of consuming an amino acid-carbohydrate supplement before and after exercise. It was revealed that ingestion of amino acids and carbohydrate prior to exercise produces a greater anabolic response than ingestion of amino acids and carbohydrate after exercise. Given these findings, to ensure that net protein anabolism occurs while resistance training, it is important be in a fed state that will provide adequate amino acids and carbohydrate prior to and during a training bout. Resistance trainees, post training, should also remain in a fed state that will provide a mixture of carbohydrates and amino acids as optimal muscle recovery has been shown to occur if ingestion of carbohydrates and amino acids occurs within 3 hours post exercise (Rasmussen et al. 2000).

Given the results of previous acute studies and those of the current study more research may be needed to further delineate if supplementation should occur and if so what dose and composition of supplement should be consumed while taking part in a periodized resistance training program. Future research should also investigate if the effects of periodized training are enhanced with a periodized dietary and or supplement strategy.

5.2 Conclusion

Although no control group was used in this study the results demonstrated that males who resistance trained and concurrently supplemented with either whey isolate protein-carbohydrate or carbohydrate over an eight week period experienced similar significant increases in strength and lean body mass with no change in total body fat or percentage body fat. Therefore, the hypothesis that trainees who supplemented with whey isolate protein-carbohydrate while training would have greater increases in muscle mass and strength than trainees consuming carbohydrate while training was rejected.

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APPENDIX A

Study Timeline

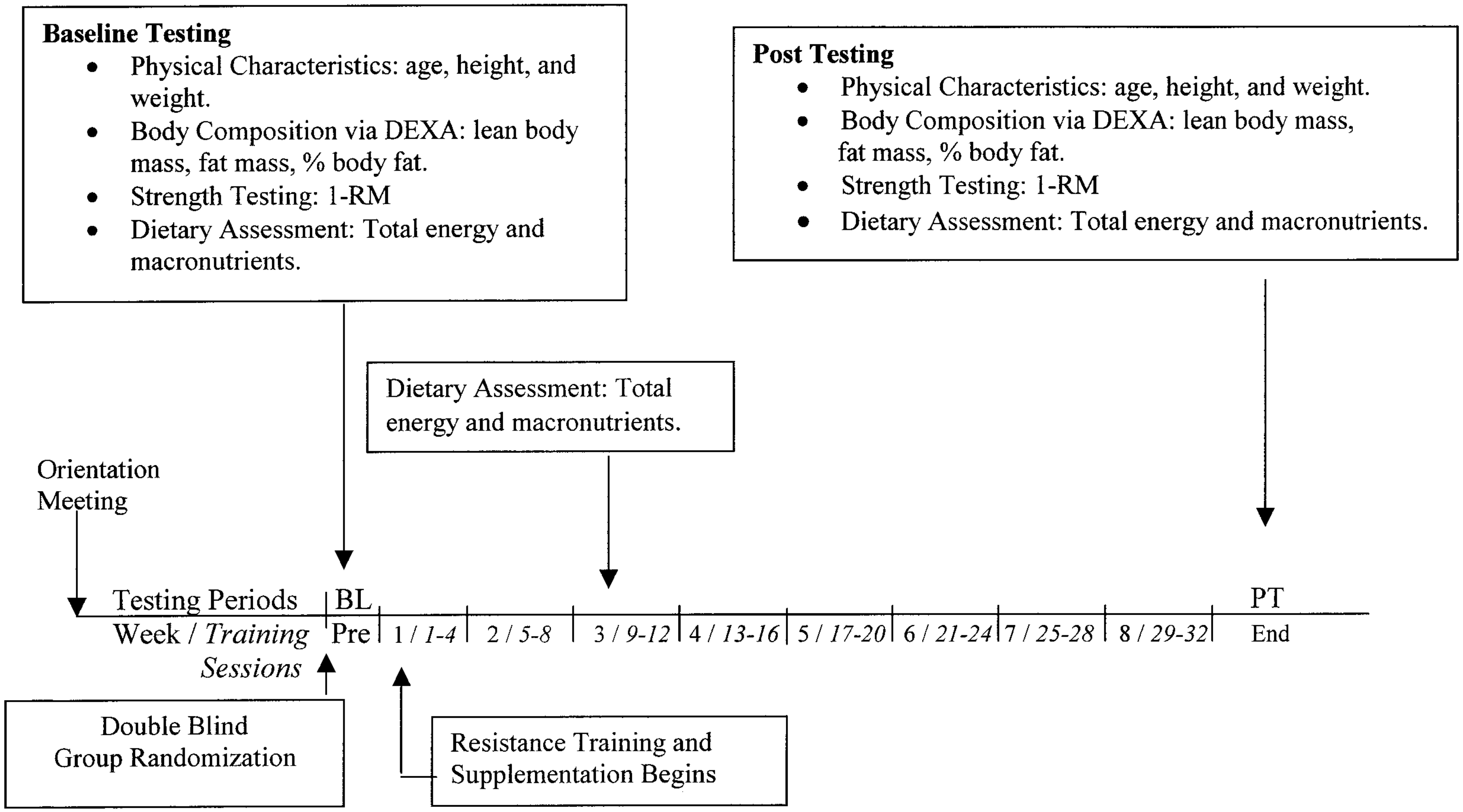

Figure A. Diagram of study timeline from baseline to completion of study

APPENDIX B

Ethics Approval Letter, Poster Advertisement

and Participant Opinion Report

UNIVERSITY OF ALBERTA

Proposal No. 2002-0530-03

Ethics Review Approval

The Ethics Committee of the Faculty of Physical Education and Recreation (University of Alberta)

Name	Position	✓ denotes primary reviewer
Dr. Wendy Rodgers (Chair)	Associate Professor	
Dr. Stu Petersen	Associate Professor	✓
Dr. Michael Mauws	Associate Professor	
Dr. Dick Jones	Professor (Pulmonary Medicine)	✓
Dr. PearlAnn Reichwein	Assistant Professor	
Mr. Mike Stickland	Graduate Student	
Mrs. Mary Andiel	External Member	

has reviewed the proposal entitled: **Body Composition and performance changes following 8-weeks of carbohydrate or whey protein-carbohydrate supplementation and concurrent resistance training.**

Investigator(s): **Mr. David Stride, Dr. Dan Syrotuik**

__X__ **Finds it within acceptable standards for human experimentation.**

_____ **Finds it within acceptable standards subject to the following revisions:**

_____ **Revise and resubmit.**

Dr. Stewart Petersen, Acting Chair, Faculty Ethics Committee

12 - 8 - 02
Date

Faculty of Physical Education and Recreation

E424 Van Vliet Centre • University of Alberta • Edmonton • Canada • T6G 2H9

RESISTANCE TRAINING & SUPPLEMENT STUDY

The Faculty of Physical Education and Recreation is seeking male subjects for a study of the effects of strength training (4 times/week for 8 weeks) and dietary supplementation (whey protein & carbohydrate or carbohydrate) on body composition, and muscular strength.

If you are between the age of 18-25 years, have actively weight trained for the past year, and have not been using protein and/or carbohydrate supplements, you may qualify for this study.

If interested, please contact Dr. Dan Syrotuik at *492-1018 or David Stride at dstride@ualberta.ca*

Participant Opinion: Protein- Carbohydrate or Carbohydrate

Please indicate with an x or √ what supplement you thought you were consuming

Protein-Carbohydrate

Carbohydrate

I do not know what supplement I was consuming

If you thought you were consuming the Protein-Carbohydrate or Carbohydrate supplement what lead you to think that you were consuming that supplement.

____

____

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____

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APPENDIX C

Whey Isolate Protein Nutritional and Amino Acid Profile

Table C1. Whey isolate protein amino acid profile

Alanine	4500	Lysine	8530
Arginine	1730	Methionine	1820
Aspartic Acid	9890	Phenylalanine	2680
Cystine	2060	Proline	5850
Glutamic Acid	15800	Serine	4070
Glycine	1480	Threonine	6420
Histidine	1540	Tryptophan	1490
Isoleucine	6170	Tyrosine	2550
Leucine	9440	Valine	5470

Values are milligrams amino acid per 100 grams product

Table C2. Whey isolate protein nutritional profile

Calories	365 kcal	Lactose	2.00 g
Calories from Fat	2.25 kcal	Protein	92.0 g
Total Fat	0.25 g	Phosphorous	214 mg
Saturated Fat	0.20 g	Calcium	433 mg
Cholesterol	2.4 mg	Magnesium	64.1 mg
Moisture	5.0 g	Potassium	484 mg
Ash	2.80 g	Iron	0.48 mg
Sodium	150 mg	Riboflavin	0.13 mg
Total Carbohydrate	4.73 g	Vitamin A	<50 IU

Values are per 100 grams of product

APPENDIX D

Dietary Caloric and Macronutrient Intake of Individual Participants

Table D1. Baseline dietary energy and macronutrient intake of individual participants within protein-carbohydrate (ProCarb) and carbohydrate (Carb) groups

A. ProCarb Group Participants (n=12)

ID#	Energy and Macronutrient Intake Energy (kcal)	Fat (g)	CHO (g)	Protein (g)	Protein (g/kg)
5	3330	130	406	127	1.4
7	3477	125	477	123	1.2
9	2627	104	324	106	1.6
11	2893	81	387	118	1.7
6	2303	88	313	73	1.0
8	3717	133	512	135	1.7
13	3730	132	478	160	2.5
10	2833	85	372	83	1.1
12	1430	42	531	78	1.1
15	2277	92	207	122	1.9
16	2147	71	303	83	1.1
14	3810	124	570	111	1.6
Mean	2881	101	407	110	1.5
S.D.	±754	±29	±109	±26	±0.4

B. Carb Group Participants (n=13)

ID #	**Energy and Macronutrient Intake** Energy (kcal)	Fat (g)	CHO (g)	Protein (g)	Protein (g/kg)
17	3590	139	396	149	2.1
20	2253	73	278	125	1.6
25	2273	36	366	126	1.8
23	1623	63	196	68	0.8
26	1913	73	243	80	1.1
27	2530	103	268	101	1.5
24	1807	64	239	75	1.0
28	2473	88	320	117	1.9
19	2827	98	339	163	2.0
29	2630	63	294	123	1.5
22	2237	79	275	112	1.6
21	2017	57	286	82	1.2
18	2523	59	347	150	1.5
Mean	2361	76	296	113	1.5
S.D.	±506	±26	±56	±31	±0.4

Table D2. Week 3 dietary energy and macronutrient intake of individual participants within protein-carbohydrate (ProCarb) and carbohydrate (Carb) groups

A. ProCarb Group Participants (n=12)

ID #	Energy and Macronutrient Intake Energy (kcal)	Fat (g)	CHO (g)	Protein (g)	Protein (g/kg)
5	3280	125	386	153	1.7
7	2233	43	408	65	0.6
9	2093	98	209	88	1.4
11	3107	119	381	140	1.9
6	2560	126	213	138	1.9
8	3780	138	500	151	1.9
13	3223	103	445	133	2
10	3173	132	348	159	2.1
12	1430	42	531	78	1.1
15	2177	180	111	124	1.6
16	2167	63	215	97	1.3
14	3113	102	480	84	1.2
Mean	2695	106	352	118	1.6
S.D.	±682	±41	±135	±33	±0.4

B. Carb Group Participants (n=13)

ID #	Energy and Macronutrient Intake Energy (kcal)	Fat (g)	CHO (g)	Protein (g)	Protein (g/kg)
17	2203	64	289	121	1.7
20	2253	73	278	125	1.6
25	2997	74	437	146	2.1
23	1970	68	268	73	0.8
27	2003	90	239	71	1.0
24	2510	74	437	71	2.1
28	2403	94	285	129	2.2
26	N.A.	N.A.	N.A.	N.A.	N.A.
19	2367	87	287	123	1.5
29	2443	111	265	96	1.1
22	1553	60	187	62	0.8
21	1897	74	214	92	1.4
18	2997	83	421	157	1.5
Mean	2300	79	301	106	1.5
S.D.	±424	±14	±85	±32	±0.5

N.A. (Not Available)

Table D3. Week 8 dietary energy and macronutrient intake of individual participants within protein-carbohydrate (ProCarb) and carbohydrate (Carb) groups

A. ProCarb Group Participants (n=12)

	Energy and macronutrient intake				
ID #	**Energy (Kcal)**	**Fat (g)**	**CHO (g)**	**Protein (g)**	**Protein (g/kg)**
5	4118	203	466	200	2.2
6	2358	81	300	91	1.3
7	3260	83	519	120	1.1
8	3885	109	556	147	1.9
9	2360	97	267	101	1.5
10	2090	82	260	83	1.1
11	3252	112	382	127	1.8
12	2077	91	385	94	1.3
13	2610	96	310	119	1.8
14	3170	131	346	80	1.2
15	2689	144	181	162	2.0
16	2270	89	230	120	1.7
Mean	2845	110	350	120	1.6
S.D.	±687	±35	±116	±35	±0.4

B. Carb Group Participants (n=13)

	Energy and macronutrient intake				
ID #	**Energy (Kcal)**	**Fat (g)**	**CHO (g)**	**Protein (g)**	**Protein (g/kg)**
17	2583	65	303	112	1.5
18	2713	81	314	126	1.3
19	2593	78	350	142	1.7
20	3520	114	354	150	1.9
21	2126	70	208	75	1.1
22	2528	81	344	92	1.3
23	1767	69	190	88	1.0
24	2344	104	234	117	1.6
25	2190	31	360	117	1.7
26	N.A.	N.A.	N.A.	N.A.	N.A.
27	2259	80	258	76	1.1
28	2197	59	362	210	3.5
29	2890	145	278	133	1.5
Mean	2476	81	296	120	1.6
S.D.	±447	±29	±62	±38	±0.7

N.A. (Not Available)

APPENDIX E

Body Composition Measures of Individual Participants

Table E1. Changes in body mass of individual participants within ProCarb and Carb groups

A. ProCarb Group Participants (n=12)

	Absolute Body Mass		
ID#	**Pre-kg**	**Post-kg**	**Change (kg)**
5	88.5	90.5	2
6	71.7	72.2	0.5
7	107	107.5	0.5
8	78.8	79	0.2
9	65.4	66.4	1
10	77	76.9	-0.1
11	70.3	70.8	0.5
12	71	72.7	1.7
13	63	66.8	3.8
14	67.5	67.5	0
15	77.5	79.5	2
16	72.2	72.4	0.2
Mean	75.8	76.9	1.0
S.D.	±12.0	±11.8	±1.2

B. Carbohydrate Group Participants (n=13)

	Absolute Body Mass		
ID#	**Pre-kg**	**Post-kg**	**Change (kg)**
17	71.6	73.3	1.7
18	100	99.2	-0.8
19	81.2	83.5	2.3
20	78.2	79.5	1.3
21	65.8	69.3	3.5
22	71.5	73.1	1.6
23	83.5	85	1.5
24	73	73.5	0.5
25	69.5	69.4	-0.1
26	71.3	72.1	0.8
27	67.6	67	-0.6
28	60.8	59.7	-1.1
29	82.6	86.5	3.9
Mean	75.1	76.2	1.1
S.D.	±10.1	±10.3	±1.6

Absolute body mass values represented are in scaled kilograms (kg), BL = baseline, PT = post training, Change = PT - BL

Table E2. Changes in lean body mass of individual participants within ProCarb and Carb groups

A. ProCarb Group Participants (n=12)

	Lean Body Mass (g)		
ID#	**BL**	**PT**	**Change**
5	73190	76554	3364
6	62966	64806	1840
7	75257	76130	873
8	66134	66601	467
9	56,995	58877	1882
10	64542	65072	530
11	54321	54781	460
12	62546	63583	1037
13	53248	55884	2636
14	55559	56917	1358
15	61405	62502	1097
16	58223	58594	371
Mean	62032.2	63358.4	1326.3
S.D.	±7022.4	±7181.3	±944.8

B. Carbohydrate Group Participants (n=13)

	Lean Body Mass (g)		
ID#	**BL**	**PT**	**Change**
17	53788	55217	1429
18	82,077	82743	666
19	62739	65386	2647
20	66423	68910	2487
21	56304	57228	924
22	55896	57542	1646
23	63553	65795	2242
24	59236	61488	2252
25	56596	58651	2055
26	50456	49676	-780
27	57601	56933	-668
28	51174	51464	290
29	56400	59822	3422
Mean	59403.3	60835.0	1431.7
S.D.	±8231.6	±8561.9	±1283.3

Values represented are in grams (g) using total body DEXA (G.E. Lunar Prodigy) scans, BL = baseline, PT = post training, Change = PT - BL

Table E3. Changes in fat tissue mass of individual participants within ProCarb and Carb groups

A. ProCarb Group Participants (n=12)

	Fat Mass (g)		
ID#	**BL**	**PT**	**Change**
5	11987	9850	-2137
6	5428	4607	-821
7	27674	27324	-350
8	8812	9016	204
9	5764	5051	-713
10	9693	8856	-837
11	12677	12417	-260
12	5538	6300	762
13	7057	8175	1118
14	9018	7880	-1138
15	12843	13647	804
16	10463	10862	399
Mean	10579.5	10332.1	-247.4
S.D.	±6012.4	±6000.6	±947.6

B. Carbohydrate Group Participants (n=13)

	Fat Mass (g)		
ID#	**BL**	**PT**	**Change**
17	14687	15082	395
18	13731	12411	-1320
19	15026	14865	-161
20	7055	6430	-625
21	6203	9052	2849
22	12164	12215	51
23	15951	15405	-546
24	10511	9156	-1355
25	9846	8418	-1428
26	17697	19424	1727
27	7279	7324	45
28	6074	5628	-446
29	22770	23231	461
Mean	12230.3	12203.2	-27.2
S.D.	±5042.2	±5270.5	±1224.5

Values represented are in grams (g) using total body DEXA (G.E. Lunar Prodigy) scans, BL = baseline, PT = post training, Change = PT - BL

Table E4. Changes in body fat percentage of individual participants within ProCarb and Carb groups

A. ProCarb Group Participants (n=12)

	Body Fat %		
ID#	**BL**	**PT**	**Change**
5	14.1	11.4	-2.7
6	7.9	6.6	-1.3
7	26.9	26.4	-0.5
8	11.8	11.9	0.1
9	9.2	7.9	-1.3
10	13.1	12	-1.1
11	18.9	18.5	-0.4
12	8.1	9	0.9
13	11.7	12.8	1.1
14	14	12.2	-1.8
15	17.3	17.9	0.6
16	15.2	15.6	0.4
Mean	14.0	13.5	-0.5
S.D.	±5.3	±5.4	±1.2

B. Carbohydrate Group Participants (n=13)

	Body Fat %		
ID#	**BL**	**PT**	**Change**
17	21.4	21.5	0.1
18	14.3	13	-1.3
19	19.3	18.5	-0.8
20	9.6	8.1	-1.5
21	9.9	13.7	3.8
22	17.9	17.5	-0.4
23	20.1	19	-1.1
24	15.1	13	-2.1
25	14.8	12.6	-2.2
26	26	28.1	2.1
27	11.2	11.4	0.2
28	10.6	9.9	-0.7
29	28.8	28	-0.8
Mean	16.8	16.5	-0.4
S.D.	±6.1	±6.4	±1.7

Values represented are in percent (%) body fat using total body DEXA (G.E. Lunar Prodigy) scans, BL = baseline, PT = post training, Change = PT - BL

Table E5. Changes in trunk lean tissue mass (g) of individual participants within ProCarb and Carb groups

A. ProCarb Group Participants (n=12)

	Trunk Lean Tissue Mass (g)		
ID#	**BL**	**PT**	**Change**
5	32060	33709	1649
6	28740	30259	1519
7	32632	33461	829
8	30984	30459	-525
9	26241	27796	1555
10	30829	30205	-624
11	24383	24148	-235
12	30424	29156	-1268
13	24591	24675	84
14	26139	26066	-73
15	29536	28402	-1134
16	26962	26992	30
Mean	28626.8	28777.3	150.6
S.D.	±2880.2	±3065.4	±1021.9

B. Carbohydrate Group Participants (n=13)

	Trunk Lean Tissue Mass (g)		
ID#	**BL**	**PT**	**Change**
17	24168	24974	806
18	39682	38814	-868
19	29210	29716	506
20	29982	31701	1719
21	26297	26385	88
22	24526	25995	1469
23	29859	30656	797
24	27399	27362	-37
25	24950	26294	1344
26	24510	24160	-350
27	27271	25919	-1352
28	22565	22255	-310
29	25546	27261	1715
Mean	27381.9	27807.1	425.2
S.D.	±4358.3	±4202.0	±994.2

Values represented are total trunk lean tissue mass using total body DEXA G.E. Lunar Prodigy) scans, BL = baseline, PT = post training, Change = PT - BL

Table E6. Changes in leg lean tissue mass (g) of individual participants within ProCarb and Carb groups

A. ProCarb Group Participants (n=12)

	Leg Lean Tissue Mass (g)		
ID#	**BL**	**PT**	**Change**
5	25909	27662	1753
6	20662	20775	113
7	26831	27054	223
8	22027	22901	874
9	19369	19316	-53
10	21684	22534	850
11	19461	19348	-113
12	20108	21115	1007
13	18163	19719	1556
14	18328	18984	656
15	20554	21775	1221
16	19454	19503	49
Mean	21045.8	21723.8	678.0
S.D.	±2752.1	±2937.0	±638.2

B. Carbohydrate Group Participants (n=13)

	Leg Lean Tissue Mass (g)		
ID#	**BL**	**PT**	**Change**
17	17609	17998	389
18	26567	27596	1029
19	21250	22246	996
20	22813	23653	840
21	19039	19548	509
22	19046	18996	-50
23	21230	21761	531
24	20172	21712	1540
25	20039	20339	300
26	16304	15405	-899
27	19609	19601	-8
28	18320	18635	315
29	20481	21531	1050
Mean	20190.7	20693.9	503.2
S.D.	±2551.0	±2981.6	±621.2

Values represented are total left and right leg lean tissue mass using total body DEXA (G.E. Lunar Prodigy) scans, BL = baseline, PT = post training, Change = PT - BL

Table E7. Changes in arm lean tissue mass (g) of individual participants within ProCarb and Carb groups

A. ProCarb Group Participants (n=12)

	Arm Lean Tissue Mass (g)		
ID#	**BL**	**PT**	**Change**
5	10662	10572	-90
6	9053	9238	185
7	11190	11128	-62
8	9019	9143	124
9	7408	7716	308
10	8140	8512	372
11	6652	7313	661
12	7942	9235	1293
13	6297	7189	892
14	7235	7880	645
15	7053	7993	940
16	7572	7883	311
Mean	8185.3	8650.2	464.9
S.D.	±1530.1	±1250.2	±426.6

B. Carbohydrate Group Participants (n=13)

	Arm Lean Tissue Mass (g)		
ID#	**BL**	**PT**	**Change**
17	8131	8306	175
18	11238	11761	523
19	8263	9340	1077
20	9427	9463	36
21	7064	7329	265
22	8083	8327	244
23	7560	8478	918
24	7234	7977	743
25	7504	8046	542
26	6220	6624	404
27	6817	7450	633
28	6428	6681	253
29	6446	7093	647
Mean	7724.2	8221.2	496.9
S.D.	±1383.9	±1387.0	±305.5

Values represented are total left and right arm lean tissue mass using total body DEXA (G.E. Lunar Prodigy) scans, BL = baseline, PT = post training, Change = PT - BL

Table E8. Changes in upper body lean tissue mass (g) of individual participants within ProCarb and Carb groups

A. ProCarb Group Participants (n=12)

	Upper Body Lean Tissue Mass (g)		
ID#	**BL**	**PT**	**Change**
5	42722	44281	1559
6	37793	39497	1704
7	43822	44589	767
8	40003	39602	-401
9	33649	35512	1863
10	38969	38717	-252
11	31035	31461	426
12	38366	38391	25
13	30888	31864	976
14	33374	33946	572
15	36589	36395	-194
16	34534	34875	341
Mean	36812.0	37427.5	615.5
S.D.	±4240.6	±4261.7	±779.7

B. Carbohydrate Group Participants (n=13)

	Upper Body Lean Tissue Mass (g)		
ID#	**BL**	**PT**	**Change**
17	32299	33280	981
18	50920	50575	-345
19	37473	39056	1583
20	39409	41164	1755
21	33361	33714	353
22	32609	34322	1713
23	37419	39134	1715
24	34633	35339	706
25	32454	34340	1886
26	30730	30784	54
27	34088	33369	-719
28	28993	28936	-57
29	31992	34354	2362
Mean	35106.2	36028.2	922.1
S.D.	±5561.9	±5504.7	±990.5

Values represented are the totals of arm and trunk lean tissue mass using total body DEXA (G.E. Lunar Prodigy) scans, BL = baseline, PT = post training, Change = PT - BL

Table E9. Changes in bone mineral content (g) of individual participants within Procarb and Carb groups.

A. ProCarb Group Participants (n=12)

	Bone Mineral Content (g)		
ID#	**BL**	**PT**	**Change**
5	3976	3948	-28
6	3654	3626	-28
7	3861	3835	-26
8	3896	3927	31
9	2779	2781	2
10	3276	3296	20
11	3293	3278	-15
12	3179	3099	-80
13	2717	2780	63
14	2820	2829	9
15	3147	3179	32
16	3226	3173	-53
Mean	3318.7	3312.6	-6.1
S.D.	440.4	430.3	40.1

B. Carbohydrate Group Participants (n=13)

	Bone Mineral Content (g)		
ID#	**BL**	**PT**	**Change**
17	2703	2713	10
18	4393	4310	-83
19	3394	3418	24
20	3890	3900	10
21	3404	3438	34
22	3515	3506	-9
23	3761	3735	-26
24	3018	3010	-8
25	2959	2963	4
26	2519	2591	72
27	2608	2586	-22
28	2650	2636	-14
29	3001	3111	110
Mean	3216.5	3224.4	7.8
S.D.	568.9	547.9	47.3

Values represented are from total body DEXA scans (G.E. Lunar Prodigy), BL = baseline, PT = post training, Change = PT – BL

Table E10. Changes in body mass of individual participants within ProCarb and Carb groups

A. ProCarb Group Participants (n=12)

	Body Mass (Kg)		
ID#	**BL**	**PT**	**Change**
5	89.2	90.4	1.2
6	72	73	1
7	106.8	107.3	0.5
8	78.8	79.5	0.7
9	65.5	66.7	1.2
10	77.5	77.2	-0.3
11	70.3	70.5	0.2
12	71.3	73	1.7
13	63	66.8	3.8
14	67.4	67.7	0.3
15	77.4	79.3	1.9
16	71.9	72.6	0.7
Mean	75.9	77.0	1.1
S.D.	12.0	11.7	1.1

B. Carbohydrate Group Participants (n=13)

	Body Mass (Kg)		
ID#	**BL**	**PT**	**Change**
17	71.2	73	1.8
18	100.2	99.5	-0.7
19	81.2	83.7	2.5
20	77.4	78.9	1.5
21	65.9	69.7	3.8
22	71.6	73.3	1.7
23	83.3	84.9	1.6
24	72.8	73.7	0.9
25	69.4	70	0.6
26	70.7	71.7	1
27	67.5	66.8	-0.7
28	59.9	59.7	-0.2
29	82.2	86.2	4
Mean	74.9	76.2	1.4
S.D.	10.2	10.3	1.5

Values represented are from total body DEXA scans (G.E. Lunar Prodigy), BL = baseline, PT = post training, Change = PT – BL

APPENDIX F

Muscular Strength of Individual Participants

Table F1. Changes in bench press strength values of individual participants within ProCarb and Carb groups

A. ProCarb Group Participants (n=12)

ID#	Bench Press 1-RM (kg) BL	PT	Change
5	116.4	122.2	5.8
6	120.0	113.3	-6.7
7	108.9	122.2	13.3
8	91.1	91.1	0.0
9	88.9	93.3	4.4
10	84.4	82.2	-2.2
11	82.2	91.1	8.9
12	77.8	86.7	8.9
13	80.0	86.7	6.7
14	71.1	80.0	8.9
15	66.7	75.6	8.9
16	64.4	75.6	11.1
Mean	87.7	93.3	5.7
S.D.	±18.6	±16.8	±5.9

B. Carbohydrate Group Participants (n=13)

ID#	Bench Press 1-RM (kg) BL	PT	Change
17	124.4	126.7	2.2
18	108.9	113.3	4.4
19	100.0	104.4	4.4
20	88.9	91.1	2.2
21	88.9	93.3	4.4
22	82.2	88.9	6.7
23	77.8	77.8	0.0
24	77.8	82.2	4.4
25	73.3	75.6	2.2
26	73.3	80.0	6.7
27	66.7	71.1	4.4
28	64.4	77.8	13.3
29	60.0	68.9	8.9
Mean	83.6	88.5	5.0
S.D.	±18.5	±17.2	±3.4

Values represented are in kilograms (kg) pressed, 1-RM = Maximum load pressed in one repetition, BL = baseline, PT = post training, Change = PT -BL

Table F2. Changes in leg press strength values of individual participants within ProCarb and Carb groups

A. ProCarb Group Participants (n=12)

	Leg Press 1-RM (kg)		
ID#	**BL**	**PT**	**Change**
5	320.0	362.2	42.2
6	231.1	271.1	40.0
7	342.2	360.0	17.8
8	262.2	293.3	31.1
9	362.2	422.2	60.0
10	262.2	275.6	13.3
11	182.2	231.1	48.9
12	257.8	357.8	100.0
13	262.2	337.8	75.6
14	160.0	211.1	51.1
15	222.2	326.7	104.4
16	213.3	235.6	22.2
Mean	256.5	307.0	50.6
S.D.	±61.2	±64.4	±30.0

B. Carbohydrate Group Participants (n=13)

	Leg Press 1-RM (kg)		
ID#	**BL**	**PT**	**Change**
17	240.0	280.0	40.0
18	324.4	386.7	62.2
19	248.9	342.2	93.3
20	240.0	280.0	40.0
21	240.0	271.1	31.1
22	304.4	320.0	15.6
23	240.0	280.0	40.0
24	271.1	360.0	88.9
25	208.9	231.1	22.2
26	191.1	213.3	22.2
27	200.0	233.3	33.3
28	262.2	281.1	18.9
29	191.1	240.0	48.9
Mean	243.2	286.1	42.8
S.D.	±40.9	±52.8	±25.0

Values represented are in kilograms (kg) pressed, 1-RM = Maximum load pressed in one repetition, BL = baseline, PT = post training, Change = PT -BL