EFFECTS OF A DIETARY MILK OR CARBOHYDRATE SUPPLEMENT WITH RESISTANCE TRAINING ON BODY COMPOSITION, MUSCLE STRENGTH AND ANABOLIC HORMONES IN UNTRAINED MEN

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Thesis submitted to the Faculty of the Virginia Polytechnic Institute and State University

in partial fulfillment of the requirements for the degree of

Master of Science

In

Human Nutrition, Foods and Exercise

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Effects of a Dietary Milk or Carbohydrate Supplement With Resistance Training on Body Composition, Muscle Strength and Anabolic Hormones in Untrained Men

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(ABSTRACT)

Twenty untrained men (18-25 y) were assigned to consume either a milk supplement (MILK) or a carbohydrate-electrolyte supplement (CHO) immediately following each resistance workout during a 10 wk resistance training program. Subjects trained 3 d/wk beginning with an intensity of 55% 1-RM and progressing to 97% 1-RM by wk 10. Muscle strength (1-RM), body composition (DEXA) and resting, fasted serum concentrations of total and free testosterone and IGF-1 were measured pre- and post-training. CHO tended to reduce, while MILK increased body weight ($P = 0.10$). All subjects significantly reduced percent body fat (1.1%) and significantly increased lean body mass (1.21 kg) as a result of the resistance training with no significant differences between treatments. However, MILK tended to increase lean body mass ($P = 0.1$) more than CHO (1.6 and 0.8 kg, respectively). About 39% of lean mass gain for all subjects was in the leg region, while the arms accounted for about 28% of lean gain. Resistance training also caused a similar significant 44% increase in muscle strength for the seven exercises combined for both groups. Resting total and free testosterone concentrations significantly decreased from baseline values in both groups of subjects (16.7% and 11%, respectively), while resting insulin concentrations significantly increased in all subjects ($P<0.01$). There were no significant changes in resting, fasted IGF-1 concentrations. In summary, dietary supplementation with a MILK or CHO beverage immediately following resistance exercise resulted in similar changes in muscle strength and hormone concentrations following a 10 wk periodized resistance training program. MILK tended to increase body weight and lean body mass more so than CHO.

Keywords: carbohydrate, periodized resistance training, testosterone, insulin, IGF-1

This research was funded by a Grant from the National Dairy Council.

ACKNOWLEDGEMENTS

I have so many people to thank for the love, help and support I received during the time I spent working on this thesis. First and foremost is my family: Mom, Dad, Todd and especially my sister, Tova, who made sure I was always doing the work I was supposed to be doing. Without their words of encouragement and constant pats on the back, I'm not sure I would be completing my Master's degree today!

I don't know what I would have done without my roommate and soon to be bridesmaid, Callie Griggs McMahon. I will never forget the endless hours we stayed awake studying and preparing for class throughout the last two years. She paved the way for me and showed me that it really can be done against all odds. I will always be thankful for that night at Macado's.

My committee members, Janet Walberg Rankin, Shelly Nickols-Richardson and Frank Gwazdauskas, gave me the guidance and assistance I needed to complete my thesis. Dr. Rankin is an incredible mentor and professor. I feel so fortunate to have worked with and learned from such a respected member of the sports nutrition community. I don't know what I would have done without the encouragement and calm words of wisdom from Dr. Nickols-Richardson. I am glad I had the opportunity to work with her both in the lab and the classroom. Her encouragement helped me stay focused and determined to finish. I am also lucky to have learned from Dr. Gwazdauskas. He spent countless hours with me in the endocrinology lab, making sure I understood each assay. From now on, I will always look for Dr. Donahue articles!

This study would never have happened without the help of Janet Rinehart. Janet taught me all I needed to know about working in the lab. She expresses the true meaning of patience and flexibility.

I would like to thank our subjects and personal trainers for their commitment and hard work throughout the entire semester. They were easy to work with (most of the time), and made my experience fun, rewarding and interesting to say the least.

There are many other people who played an integral part in this project, and without whom I would never have finished. Michael Puglisi, my partner, took half of the responsibilities out of my hands. I cannot imagine completing this thesis without his help. Randy Bird went out of his way to give advice and lend a hand whenever and wherever I needed his assistance. There were many others who helped out along the way as well. Dr. Carrie Earthman and Max Shute helped take body composition and resting metabolic rate measurements. Anika and Pat Boyle assisted with hormone assays in the endocrinology lab. I cannot forget my undergraduate assistants, Katharine Brown, Erika Christensen and Jarrod Stork. Their commitment to this project was unbelievable.

Finally, I have to thank my fiancee and best friend Alex Barkan. I appreciate his patience and understanding each and every time I needed to vent or complain. He was with me

every step of the way these last few years, and I don't know what I would have done without his love and support. May can't come soon enough!

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CHAPTER 1:

Introduction

The widespread utilization of nutritional supplements among people who are trying to get stronger and look bigger has sparked a dramatic increase in US supplement sales. In a recent survey including almost 14,000 collegiate athletes, 26% of respondents reported extensive use of nutritional supplements (48). However, many of these supplements are very expensive and have yet to be proven effective. Body builders are a prime target for supplement companies. Even though it is shown that a long term resistance training program alone can promote significant increases in muscle strength and muscle mass, many of these athletes are looking for a way to reach their goals faster, and therefore turn to nutritional supplements.

The supplements designed to increase muscle mass and decrease body fat are most popular among body builders. However, the popularity of these supplements is not restricted to professional body builders. Many recreational athletes have also incorporated these supplements into their daily routine. More than 40% of American's report using some sort of alternative medicine, including herbals and nutritional supplements. The use of megavitamins by the average adult increased by 130% from 1990-1997 (44). Despite the lack of research to support the claims, the popularity of nutritional supplements has spread throughout the country. People other than athletes, such as the elderly and the sick may also benefit from anabolic nutritional supplements, as they are at an increased risk of losing muscle mass and strength. There is some interest into the mechanisms to delay or minimize this loss.

The safety of these supplements should be a concern to consumers. There is very little research available that can prove safety for long term utilization of these supplements. In 1994, the Dietary Supplement Health and Education Act (DSHEA) was passed, which allows supplement companies to make claims about affecting structure and function, but cannot claim to treat, prevent, diagnose or cure a disease (44). The Food and Drug Administration does not have to approve dietary supplements; nor do supplements have to be proven safe or effective before they are brought to the market. Therefore, designing a supplement that is relatively inexpensive, proven effective and safe for long term use could have a significant impact on the future of supplement companies.

Long term resistance training may increase basal concentrations of certain hormones associated with protein metabolism. The increased concentration of these hormones may be the mechanism behind muscle protein accretion. A supplement that promotes the actions of these hormones should lead to significantly more gains in muscle strength and muscle mass. Milk may be the optimal nutritional supplement to promote these gains because it contains both protein and carbohydrate.

Timing of the supplement is also very important. Some research shows that consuming a snack that contains carbohydrate and amino acids immediately following a workout may lead to significant gains in lean body mass in individuals participating in a resistance training program, while other research identifies the benefit of supplements consumed before exercise.

Statement of the Problem

The ideal combination of nutrients that promotes the most accretion in muscle mass and muscle strength is still controversial. Dietary protein and carbohydrate may serve as natural anabolic supplements. Dietary protein has been found to promote muscle protein metabolism, while dietary carbohydrate stimulates the release of anabolic hormones such as insulin. However, the research looking at dietary factors such as protein and carbohydrate in combination with resistance training is lacking, and what is available is very short term. There is currently no research available to show the long term benefits of a protein-carbohydrate mixture taken in combination with resistance training.

Milk may be an ideal supplement because it contains both protein and carbohydrate, is easily accessible to the public and is less expensive than most nutritional supplements. Supplementation with milk, along with a long-term resistance training program may promote significant changes in body composition and muscle strength. Many different populations may benefit from milk supplementation along with a weight training program to help reduce muscle mass loss or significantly promote muscle hypertrophy, and therefore this research may have implications for people who want to maximize the benefits of resistance training on body composition and muscle strength.

Objectives

♦ To examine the changes in body composition following 10 wk of resistance training when subjects consume either a milk or carbohydrate supplement after each workout.

♦ To examine the changes in muscle strength following 10 wk of resistance training with either a milk or carbohydrate supplement.

♦ To determine whether the changes in basal hormone concentrations related to protein metabolism (total testosterone, free testosterone, insulin and IGF-1) are correlated to changes in body composition or strength following 10 wk of resistance training with either a milk or carbohydrate supplement.

♦To determine whether overall dietary quality is different in subjects who consume a milk or carbohydrate supplement following each workout over a 10 wk period.

Hypotheses

H_0: There will be no difference in muscle hypertrophy or body fat change over 10 wk of resistance training between the milk-supplemented group and the carbohydrate-supplemented group.

H_0: There will be no difference in strength gains over 10 wk of resistance training between the milk-supplemented group and the carbohydrate-supplemented group.

H_0: There will be no association between basal concentrations of total testosterone, free testosterone, insulin or IGF-1 and fat free mass gain after a 10 wk resistance exercise program.

H_0: There will be no difference in overall dietary quality between supplemented groups.

Delimitations

∗ The subjects were untrained, apparently healthy males age 18-25 who agreed to forego all nutritional supplements for 1 mo prior to and during the study.

∗ None of the subjects was allergic to milk or lactose intolerant.

∗ The exercises used during the periodized model of resistance training program were abdominals, leg press, leg extension, leg curl, bench press, shoulder press, lat pull down, and arm curl (Bodymasters).

∗ Performance of the resistance workouts was verified by personal trainers.

∗Consumption of the test beverages was verified by experiment personnel.

Limitations

∗ The exercise machines were unfamiliar to the subjects. We did not incorporate a familiarization period in with the 10 wk study.

∗ There was variation among subjects in form during lifting that may have influenced strength gains.

∗ There was a wide variation in initial body weight, body composition and strength among the subjects.

∗ Other unmeasured hormones may be critical in the hypertrophy process.

∗ The duration of the resistance training program may have been inadequate to detect differences in the treatment groups.

∗ There was no control group.

∗ Dietary quality was assessed from 3 d diet records. Although each subject was instructed on proper recording, there is never complete accuracy.

Basic Assumptions

♦ It was assumed that none of our subjects had participated in a regular resistance training program for at least 3 mo prior to the start of the study and were not involved in any weight training outside of the study.

♦ It was assumed that none of our subjects were taking any nutritional supplements for 1 mo prior to or during the study.

♦ It was assumed that each subject gave his maximum effort for each of the strength tests.

♦ It was assumed that the subjects gave a fair and accurate report of their dietary intake for each 3 d food record period.

♦ It was assumed that the subjects fasted for 12 h prior to each blood draw.

♦ It was assumed that subjects did not purposely alter their diet or activity outside the resistance training program.

Summary

Resistance training alone can promote significant gains in muscle strength and muscle protein. Combining this with nutritional supplementation may lead to even more increases. Limited evidence suggests that a mixture of protein and carbohydrate may be the most beneficial nutritional supplement to achieve these goals.

Many studies show that hormones associated with protein metabolism, total testosterone, free testosterone, insulin and IGF-1 are increased immediately following resistance exercise (11, 22, 41, 87). Other research shows that consuming a snack immediately following exercise promotes muscle protein turnover (68). Therefore, consuming a nutritional supplement immediately following exercise may lead to increases in protein metabolism and over time, increases in muscle protein.

Milk may be the most beneficial nutritional supplement for the promotion of muscle hypertrophy and strength gains. It is hypothesized that a milk supplement, consumed immediately following exercise, will lead to more significant increases in muscle mass and muscle strength than a carbohydrate beverage after 10 wk of weight training.

Definitions and Symbols

- **RM** Repetitions maximum. In weight lifting, the most weight that can be used in a single exercise for a certain number of repetitions.
- **Leg Pr** Leg press
- **Leg Ext** Leg extension
- **Bench Pr** Bench Press
- **Shoulder Pr** Shoulder press
- **Lat Pull** Lateral pull down
- **FFM** Fat-free mass
- **DEXA** Dual-energy x-ray absorptiometry (Hologic QDR4500A)
- **% BF** Percent body fat
- **IGF-1** Insulin-like growth factor 1
- **CHO Group (CHO)** The group of subjects (n=10) who received 5 kcal/kg of a carbohydrate beverage following each workout during the 10 wk study.
- **Milk Group (Milk)** The group of subjects (n=9) who received 5 kcal/kg of low fat chocolate milk following each workout during the 10 wk study.

CHAPTER 2:

Review of Literature

Introduction

Resistance training is a positive stimulus for muscle hypertrophy and increases in muscle strength. A net positive protein balance occurs when muscle protein synthesis is greater than muscle protein degradation, and results in muscle hypertrophy. An acute bout of weight lifting has been shown to promote increased muscle protein synthesis as well as increased muscle protein breakdown, however, it is assumed that with continued weight training, this will lead to muscle hypertrophy due to an overall elevation in protein synthesis over degradation.

In order to maximize muscle hypertrophy, it is necessary to optimize the factors which promote protein synthesis and reduce protein degradation. Exercise has a major effect on protein metabolism. The frequency, intensity and type of exercise all have a role in determining protein balance. Diet also plays an important part in regulating protein metabolism, as diet combined with resistance exercise increases protein synthesis without affecting protein breakdown. Many athletes, both competitive and recreational, have turned to dietary supplements to help them get the most out of their workouts.

Research has shown that an acute bout of weight training affects the concentration of many hormones involved in protein metabolism, such as testosterone, insulin and IGF-1. More research is needed to examine the effects of a prolonged weight training program on basal concentrations of these hormones. There is evidence to show that

increased levels of these hormones in the blood are associated with positive net protein balance. Dietary factors may also influence the changes in these hormones in response to resistance training (55, 88).

Combining resistance training with appropriate nutrient consumption is likely to provide the substrates for protein synthesis as well as the maximal hormonal changes to positively impact protein balance. One study showed that consuming a protein-carbohydrate mixture 1 h following a resistance exercise bout caused a marked increase in plasma insulin, which coincided with a significant increase in net protein balance (68). More research is needed to examine the effects of dietary supplementation content and timing with resistance training exercise on protein metabolism.

The following review of literature will focus on the effects of protein and carbohydrate supplementation and resistance training on certain hormone concentrations and the resulting effects on body composition and muscle strength.

Prescriptions of resistance exercise- effect on muscle hypertrophy and strength

Muscle hypertrophy results when muscle protein synthesis exceeds muscle protein degradation. Resistance exercise has a profound effect on protein metabolism. In addition to the characteristics of the subject (age, gender, training status), the frequency, duration and intensity of exercise are important factors determining the magnitude of muscle hypertrophy.

Research shows that as little as 8 wk of resistance training is sufficient to show significant improvements in body composition and strength in untrained men (Table 1).

Table 1. Body composition and strength changes with resistance training programs

STUDY	SUBJECTS	FREQUENCY	SETS/REPS	INTENSITY	STRENGTH GAINS (1 RM)	BODY COMPOSITION CHANGES	
Abe (1)	17 untrained M (aged 25-50)	3d/wk; 12 wks	1 or 3 sets; 8-12 reps	8-12 RM	19% KE&CP	BF: +0.5%	FFM: +1.6 kg
Braith (14)	19 untrained M&F (mean age = 26)	3d/wk; 10 wks	1 set; 7-10 reps	7-10 RM	21% KE	N/A	N/A
Broeder (15)	64 M, unknown training status (aged 18-35)	4d/wk; 12 wks	3 sets; 10-12 reps (1), 8-10 reps (2), 6-8 reps (3)	1. 10-12 RM 2. 8-10 RM 3. 6-8 RM	19.3% (upper) 10.3% (lower)	BF: -2.8%	FFM: +2.1 kg
Broeder (16)	64 untrained M (aged 18-35)	4d/wk; 12 wks	3 sets; 10-12 reps (1), 8-10 (2), 6-8 (3)	80% 1 RM	N/A	BF: -3%	FFM: +2.5 kg
Brown (17)	30 untrained M (aged 19-29)	3d/wk; 8 wks	3 sets; 10 reps (2 wks) 3 sets; 8 reps (last 6 wks)	80-85% 1 RM	23.6% (upper) 42.8% (lower)	BF: -1.4%	FFM: +2.9 kg
Craig (24)	6 M, training status unknown (mean age = 23)	3d/wk; 12 wks	3 sets; 8-10 reps	8-10 RM	N/A	BF: -1.8%	FFM: +0.9 kg
Cureton (25)	7 untrained M (aged 22-37)	3d/wk; 16 wks	1-3 sets; as many reps as possible	70-90% 1 RM	30% (overall)	FM: -1 kg	FFM: No change
Dolezal (27)	30 trained M (mean age = 20)	3d/wk; 10 wks	3 sets; 10-15 reps (wks 1-2), 10-12 reps (I), 8-10 reps (II), 4-8 reps (III) (next 8 wks)	Wk 1: 10-15 RM Wk 2-10: 1. 10-12 RM 2. 8-10 RM 3. 4-8 RM	25% (overall)	BF: -1.4%	FFM: +2.3kg
Kraemer (53)	8 untrained M (mean age = 30)	3d/wk; 10 wks	M: 4 sets; 3-5 reps W: 4 sets; 8-10 reps F: 4 sets; 12-15 reps	M. 3-5 RM W. 8-10 RM F. 12-15 RM	15% (LS)	BF: not measured	FFM: +10% (thigh MCSA)
Lemon (57)	14 untrained M (mean age = 22)	6d/wk; 8 wks	4 sets; <10 reps	70-85% 1 RM	5.9% (BP-PRO) 9.3% (BP-CHO) 18.4% (LS-PRO) 2.4% (LS-CHO)	BF: -1% (PRO) +.5% (CHO)	FFM: +1 kg (PRO) no change (CHO)
McCall (59)	11 active M (aged 18-25)	3d/wk; 12 wks	3 sets; 10 reps	10 RM	25% (overall)	BF: not measured	FFM, +9.79 cm^2 (total arm MCSA)
Mazzetti (61)	20 trained M (aged 18-35)	4 phases: wk 1-2: 2-3d/wk wk 3-6: 4d/wk wk 7-10: 3d/wk wk 11-12: 3d/wk	I: 3 sets; 12 reps II: 3 sets; 8-10 reps III: 3-4 sets; 6-8 reps IV: 2-3 sets; 3-6 reps	1. 12 RM 2. 8-10 RM 3. 6-8 RM 4. 3-6 RM	25% (upper) 33% (lower)	BF: +2.10%	FFM: +1.38kg
Staron (75)	13 untrained M (mean age = 23)	2 d/wk; 8 wks	3 sets; 6-8 reps (d1), 10-12 reps (d2)	D1: 6-8 RM D2: 10-12 RM	N/A	BF: -2.1%	FFM: +1.8 kg
Volek (87)	19 trained M (mean age = 25)	4 phases: wk 1-2: 3d/wk wk 3-6: 4d/wk wk 7-10: 3d/wk wk 11-12: 3d/wk	I: 3 sets; 12 reps II: 3 sets; 8-10 reps III: 3-4 sets; 6-8 reps IV: 2-3 sets; 3-6 reps	1. 12 RM 2. 8-10 RM 3. 6-8 RM 4. 3-6 RM	24% (LS) 16% (BP)	FM: +0.9 kg	FFM: +2.1 kg
Yarasheski (94)	18 untrained M (mean age = 27)	5d/wk; 12 wks	4 sets; 4-8 reps	75-90% 1 RM	50% (overall)	FM: -0.2 kg	FFM: +1.6 kg

1 RM- one repetition maximum; KE- knee extension; CP- chest press; LS- leg squat; BF- % body fat; FM- fat mass; FFM- fat free mass; M- Monday; W- Wednesday; MCSA- muscle circumference surface area; PRO- protein; CHO- carbohydrate

With induction of a resistance training program, previously untrained subjects undergo adaptations in both the nervous system and within the muscle itself, and the time course for muscle hypertrophy varies (75). For example, one study showed that untrained men involved in an 8 wk resistance training program, working 3 d a week at 80-85% 1 RM for three sets and 8-10 repetitions, increased lean body mass (LBM) by 2.9 kg and had a 1.4% reduction in body fat (17). Subjects in this study also showed a 23.6% increase in upper body strength and a 42.8% increase in lower body strength.

In a more recent study, Abe et al. (1) saw a 19% increase in subjects' 1-RM for knee extension and chest press, which reached significance by the second and sixth week of training, respectively. Although no significant changes were observed in percentage body fat, subjects accrued a 1.6 kg increase in LBM after 12 wk of training. In this study, 17 middle-aged untrained males completed either one or three sets of 8-12 RM for knee flexion, seated row, elbow flexion, elbow extension, knee extension and chest press 3 d/wk.

Cureton et al (25) used seven untrained men in their 16 wk resistance training protocol, which included 3 d/wk, one to three sets with as many repetitions as possible at an intensity which progressively increased from 70-90% of 1-RM by the end of the training period. The training program was designed to promote hypertrophy in the flexor and extensor muscles of the upper arms and legs. Although insignificant, muscle cross-sectional area (CSA) in the arm increased 16%, while thigh CSA increased by 1.7%. Upper and lower body strength increased 30% on average.

Similar results have been seen other studies with resistance exercise programs including trained subjects. In a study by Dolezal and Potteiger (27), 30 active men

participated in a 10 wk resistance training program designed to promote increases in muscle strength. The subjects performed 13 upper and lower body exercises 3 d/wk at 10-15 RM for the first 2 wk and then increased the load to 10-12 RM for the first set, 8-10 RM for the second set and 4-8 RM for the third set. Subjects significantly reduced their percentage body fat by 1.4% and significantly increased fat free mass (FFM) by 2.3 kg at the end of the 10 wk. Significant increases were also seen in the 1-RM leg squat (23%) and bench press (24%).

Periodized training programs are designed to maximize gains in strength, power and muscle mass. Usually split into phases, each phase is intended to focus on one aspect of training (preparatory, hypertrophy, strength, power). In one study using women volunteers, a 6 mo periodized training regimen resulted in significant whole body and regional losses in body fat and gains in FFM (65). Subjects in this study trained 5 d/wk for 1.5 h each day. The number of repetitions for each set began at 10-12, but increased as the weight was reduced within the same exercise until the midpoint of training. From that point until the end of the program, the number of repetitions was reduced as the weight was increased. Body composition changes reached significance after 14 wk of training. Whole body FFM increased by 0.9 kg, most of which came from the leg region (0.7 kg), and whole body fat mass (FM) decreased 2.6 kg, with the majority lost from the arms (1.1 kg) after 24 wk of training. This study shows that periodized resistance training can lead to significant changes in body composition after 14 wk of training in previously untrained women.

In another periodized resistance training designed protocol, 19 trained men significantly increased total body mass by 3.0 kg, FFM by 2.1 kg and also increased FM

by 0.9 kg over 12 wk (87). Muscle strength of subjects, as observed by the increased 1-RM leg squat and bench press (24% and 16%, respectively). This training program included four phases. The first 2 wk were designed as general preparatory and included three sets at 12 RM. Weeks three to six were the hypertrophy phase and included three sets at 8-10 RM. The strength phase lasted from weeks seven to ten and included three to four sets at 6-8 RM. The last phase was the peaking phase, which consisted of two to three sets at 3-6 RM. This study showed such a program can induce significant changes in men who were already resistance-trained.

In summary, heavy resistance training over an 8-14 wk period has been shown to significantly increase overall 1 RM strength gains in the range of 19% to 50% as well as to promote gains in muscle mass up to 2.5 kg and reductions in percentage body fat up to almost 3% (1, 14-16, 24, 25, 27, 53, 57, 59-61, 75, 87, 94).

Effect of protein intake with resistance training on muscle hypertrophy and strength

Dietary protein is important for muscle growth, but researchers are not yet sure about how much protein is required by resistance trainers, and whether a protein supplement will aid in muscle gains. Tarnopolsky et al. (78) determined that a protein intake of 1.41 g/kg each day was adequate to achieve nitrogen balance in strength trained subjects, while 0.9 g/kg was the protein requirement for sedentary subjects. A higher protein intake of 2.4 g/kg did not improve nitrogen retention or protein synthesis, as measured by leucine turnover, in the resistance trained group. Although there are many factors (age, gender, type and intensity of exercise) that determine protein needs of an individual, current research agrees that for those participating in regular strength training, a daily protein intake of 1.6 to 1.8 g/kg is sufficient to maintain protein balance (56).

Other research has focused on the potential value of protein supplements for optimal muscle hypertrophy. The reasons behind protein/amino acid supplementation include promotion and maintenance of muscle hypertrophy and muscle strength, enhancement of energy utilization and stimulation of the release of various anabolic hormones (93). In one study, nine trained male subjects consumed either a supplement consisting of 7.9 kcal/kg and 0.7 g/kg of protein (33%) plus 1.3 g/kg of carbohydrate (67%) or a placebo consisting of minimal calories, protein and carbohydrate a day for 1 wk (55). Subjects participated in a heavy resistance training protocol for the last consecutive 3 d of each dietary treatment week. Total energy intake was 1,368 kcal higher, protein was 120 g higher, carbohydrate intake was 220 g higher and fat intake was 8 g lower during the week of supplementation. There were no differences between the two treatments in number of repetitions or total volume of weight lifted over the 3 d, however during supplementation, subjects had significantly higher total body mass at each of the three training sessions (+0.8 kg, +1.6 kg, +1.3 kg, respectively), although there were no significant changes in skinfold thickness or muscle circumference. The apparent lack of increase in LBM may be explained by the fact that nitrogen balance is maintained in trained individuals who follow a consistent workout pattern without an increase in protein intake after the initial period of adaptation to resistance exercise (93). Therefore, the increase in body weight may not indicate an increase in LBM in these already trained subjects.

Another study reported that 14 untrained males, who participated in a 6 d/wk resistance training program, consisting of four sets of as many repetitions as possible at 70-85% 1 RM, along with adding a 1.5 g/kg protein supplement in their regular dietary

intake, promoted the same strength and hypertrophy gains as the 1.5 g/kg carbohydrate-supplemented group after the 1 mo training program (57). The carbohydrate supplement promoted a 6.2% increase in muscle density and a 9.3% increase in 1-RM bench press along with a 2.4% increase in 1-RM leg squat. Subjects who consumed the protein supplement saw a 5% increase in muscle density along with a 5.9% increase in 1-RM bench press and an 18.4% increase in 1-RM leg squat. However, nitrogen balance was significantly more positive during the protein period, as all subjects were in negative nitrogen balance with the carbohydrate treatment. This study shows that although including a 1.5 g/kg protein supplement in combination with a resistance exercise program over 4 wk did not promote more strength or hypertrophy gains than a 1.5 g/kg carbohydrate supplement, the positive nitrogen balance seen with the protein treatment should theoretically lead to better muscle gains in the long term.

Other studies have looked at the changes in body composition and strength in elderly subjects after a resistance training program in combination with a dietary supplement. Campbell et al. (19) recruited 12 untrained men and women, aged 56-80 y for their study, which compared different protein intakes in older adults involved in weight training. Subjects were assigned to a dietary treatment equal to either the RDA for protein (0.8 g/kg/d) or twice the RDA for protein (1.6 g/kg/d). Some of the protein (0.6 g/kg) was provided in the diet, while the remaining protein requirement was provided as milk-based beverages. The study also included a 3 d/wk training program including three sets of 8-12 repetitions at 80% 1 RM for four exercises for 12 wk. The higher protein group significantly increased FFM by 1.8 kg and reduced percent BF by 2.3%, while the lower protein group significantly increased FFM by 1.0 kg and reduced

percent BF by 2.1% compared to their baseline values, however there were no significant differences between groups. Also, both treatments led to similar increases in nitrogen retention and nitrogen balance, indicating a greater efficiency for nitrogen retention in the lower protein group. This study shows that in untrained elderly men and women, including a dietary protein supplement to equal a protein intake of 0.8 g/kg in combination with a resistance exercise program can promote protein synthesis and more efficient nitrogen retention than a protein intake of 1.6 g/kg. Meredith et al. (62) had 12 untrained non-obese males, aged 61-72 y complete a 12 wk resistance training protocol, and either include a daily supplement (560 kcal: 23.8 g pro, 60.2 g CHO, 24.8 g fat) or no supplement. The supplemented group consumed significantly more protein by the final week of testing than the unsupplemented group (1.6 g/kg vs. 0.93 g/kg, respectively) and the supplemented men increased their overall body weight by 2.2 kg, while total body weight decreased by 1.6 kg in the unsupplemented men. The sum of six skinfolds increased by almost 9% in the supplemented group, while there was no change in the unsupplemented group. Also, 1-RM of knee extensor (KE) improvements were similar between both groups by the end of the 12 wks. Thus, the research has shown that a dietary supplement including protein in combination with resistance training improves body composition in the elderly more than resistance training alone.

Looking at the effects of a single bout of resistance exercise on muscle protein metabolism both with and without dietary manipulation may provide insight to the effects of long term resistance training along with consumption of a dietary supplement. Initially, studies have used infusion to increase the supply of amino acids. In one study, six untrained young males were infused with an amino acid mixture (0.15 g/kg/h) at rest

and immediately following leg exercises for 3 h (10). They found that supplying the amino acids at rest increased protein synthesis by 100%, whereas hyperaminoacidemia immediately following exercise increased protein synthesis up to 200%. Although resistance training alone increases muscle protein breakdown, there was no change from baseline when amino acids were infused. Tipton et al. (80) looked at the effects of orally administered amino acids following resistance exercise on muscle protein metabolism in untrained young males. Subjects had 4 h and 15 min to consume an amino acid solution (40 g) following exercise. Plasma amino acid concentrations significantly increased after consumption of the solution, which led to an overall more positive nitrogen balance (+29 nmol/min/100 ml leg vol) when compared to the placebo (-50 nmol/min/100 ml leg vol). These studies show that increased amino acid availability immediately following resistance exercise may maximize the anabolic effect of exercise alone, although the exact mechanism is not yet clear.

Studies have shown that increased amino acid availability with a single bout of resistance exercise resulted in elevated rates of protein synthesis and a more positive nitrogen balance. Other studies found that with a long term resistance training program, dietary protein supplementation led to increased muscle hypertrophy and muscle strength when compared to no supplementation. Therefore, it seems that over a longer period of time, resistance training along with dietary protein supplementation may promote increased protein synthesis, a state of positive nitrogen balance and more gains in muscle hypertrophy and strength.

Effect of CHO supplementation with long term resistance exercise on muscle hypertrophy and strength

Carbohydrate (CHO) is promoted as the primary post-exercise beverage, however there is little research looking specifically at the effects of CHO supplementation with long-term resistance training on muscle protein metabolism.

Generally, research speculates that CHO ingestion affects protein metabolism indirectly, either through substrate metabolites or hormonal regulation (81). Roy et al. (72) found that a 1 g/kg CHO drink immediately post-exercise during a strenuous resistance training program led to a decrease in muscle protein degradation (MPD) compared to resistance exercise with placebo ingestion. However, they detected no significant changes in fractional synthesis rate (FSR), despite increased insulin concentrations for the carbohydrate group. In this study, eight trained young males participated in two exercise trials. In one trial (CHO), subjects received a carbohydrate beverage (1g/kg glucose) immediately (1900 h) and 1h following the exercise bout (2030 h) and a placebo beverage (Nutrasweet) with breakfast (0700 h). In the other trial (PL), subjects consumed a carbohydrate beverage (2 mg/kg glucose) with breakfast and then a placebo beverage immediately and 1 h following exercise. Plasma insulin levels were significantly higher for up to 2 h following consumption of the first beverage in the CHO trial compared to PL. MPD, as measured by 3-methylhistidine excretion, was significantly lower for the CHO trial than the PL, and the exercised leg showed a trend toward greater muscle protein synthesis (36.1%) when compared to the control leg (6.3%). The authors suggested that the increase in FSR may have been limited by the reduced amino acid availability due to the glucose administration, since other studies

have shown that hyperinsulinemia along with hyperaminoacidemia promotes protein synthesis. However, this study shows that a 1 g/kg glucose supplement consumed immediately and 1 h following resistance exercise may enhance muscle protein balance.

In a follow-up study, Roy et al. (71) found that consumption of a supplement including carbohydrate, protein and fat or a supplement consisting of carbohydrate alone immediately and 1 h following a single bout of resistance exercise resulted in a significant increase in protein synthesis. Ten trained subjects completed each of the following treatments: carbohydrate/fat/protein (66% CHO, 23% PRO, 12% FAT), carbohydrate alone (1 g/kg glucose) and placebo (sucralose). Supplements were consumed immediately and 1 h following a bout of resistance exercise. There were no significant differences between treatments in 24 h urinary creatinine excretion, 3-methylhistidine excretion or urinary urea nitrogen excretion. However, at 4 h post-exercise, whole body leucine oxidation, which indicates amino acid oxidation, was significantly elevated for the combination supplement versus the other two treatments and non-oxidative leucine disposal (NOLD), an indicator for protein synthesis, was significantly increased for the carbohydrate/protein/fat (41%) and carbohydrate alone (33%) supplements compared to the placebo. Although no significant changes were noted in protein degradation, protein synthesis significantly increased following a bout of resistance exercise and ingestion of a combination supplement consisting of carbohydrate, fat and protein or a supplement including carbohydrate alone.

In another study, Lemon et al. (57) supplemented their subjects with 1.5 g/kg of carbohydrate in addition to their regular diet. After an intensive month-long resistance training program, subjects taking the CHO supplement had similar increases in their 1-

RM bench press and muscle density as subjects taking a 1.5 g/kg protein supplement. The research shows that a dietary supplement containing carbohydrate in addition to acute resistance exercise enhances muscle protein balance by either promoting the rate of protein synthesis or by reducing the rate of protein degradation. When resistance training is continued over a longer period of time, this treatment may lead to greater increases in muscle strength and muscle hypertrophy.

There is very limited research looking at the combined effect of a carbohydrate-protein supplement along with resistance training. One study conducted by Rasmussen et al. (68) tested the effect of a carbohydrate plus protein beverage fed either 1 or 3 h after resistance exercise on muscle protein metabolism. Six untrained men and women served as subjects for the study. The experimental drink was composed of 6 g of essential amino acids plus 35 g of sucrose in 500 ml of water. Subjects completed two trials: receiving either the treatment beverage and then the placebo at 1 and 3 h postexercise, or vice versa. The training program included ten sets of eight repetitions for the leg press and eight sets of eight repetitions for leg extension at 80% 1-RM. The treatment beverage significantly increased muscle protein synthesis at 1 h and 3 h, but had no effect on muscle protein breakdown when the drink was consumed either 1 or 3 h after exercise. Insulin concentrations significantly increased after consumption of the treatment beverage at both time points and peaked between 20 to 30 min after ingestion. This study shows that a carbohydrate-amino acid supplement promotes muscle protein synthesis when consumed immediately following exercise, but does not provide a comparison to a carbohydrate-only beverage.

In summary, some studies have tested only carbohydrate, while others have used a combination supplement. More studies comparing a carbohydrate alone supplement to a carbohydrate with protein supplement in combination with a long term resistance training program are required to determine which nutritional intervention is superior for the promotion of muscle hypertrophy and increased muscle strength.

Effect of resistance exercise on plasma insulin concentrations

To date, there is not much research available looking at the effects of resistance training on resting plasma insulin levels, and that which is available is controversial. One study showed that 1 wk of resistance exercise did not affect basal insulin concentrations in nine resistance-trained men (55). In another study, Yarasheski et al. (94) measured insulin concentrations before, after 6 wk and after 12 wk of resistance training in their 18 untrained male subjects. Fasting insulin concentrations were unchanged with training, however the area under the insulin curve following glucose ingestion was lower after 12 wk when compared to pre-training levels, indicating an improved insulin sensitivity with exercise. It may be that a longer period of resistance training would have a more potent effect on insulin concentrations in previously untrained men, however, the current research shows no effect of resistance training on resting insulin concentrations.

However, studies have confirmed that dietary intake in combination with resistance exercise may cause changes in circulating levels of plasma insulin. For example, Kraemer et al. (55) found that with protein-carbohydrate supplementation 2 h before and immediately following a bout of resistance exercise, serum insulin levels were significantly greater at 15 and 30 min post-exercise on the 3rd day of supplementation compared to placebo. In another study, subjects who consumed either a carbohydrate

only (1.5 g/kg) or a carbohydrate-protein supplement (1.06 g/kg CHO, 0.41 g/kg PRO) immediately and 2 h following a weight training workout had significantly higher plasma insulin concentrations than subjects who consumed a protein only supplement (1.38 g/kg) by 8 h after the workout and 2 h following the second supplement (22).

Although a long term resistance training program alone may not affect resting insulin concentrations, it is possible that resistance exercise in combination with a dietary supplement containing carbohydrate and protein may lead to changes in basal insulin levels.

Effects of resistance exercise on serum total and free testosterone concentrations

Studies looking at acute changes in hormone levels immediately following exercise show significant increases in testosterone concentrations when compared with pre-exercise levels from 14-26% (22, 41-43, 50, 88). For example, Volek et al. (88) showed that serum testosterone levels significantly increased following five sets of ten repetitions of bench press (7.4%) and jump squat (15.1%) at 30% 1-RM compared to baseline values. The amount of change in this hormone in relation to resistance exercise may be the result of three factors: exercise intensity, volume of exercise and the amount of muscle tissue used during exercise (51).

Increases in resting serum testosterone have also been observed in some studies of long term resistance training programs. Tsolakis et al. (83) demonstrated that untrained high school children (mean age = 14.9 ± 0.9 y) participating in a 2 mo resistance training study significantly increased basal total testosterone levels by 32% over pre-training values. Another study showed that basal concentrations of total testosterone significantly increased (30%) above baseline levels after just 4 wk of weight training in untrained

young men (mean age = 23.5 y) (75). Total testosterone in eight untrained middle aged men (mean age = 30 y), who participated in a 10 wk periodized weight training program, tended to increase after just 3 wk of training (15%), but then declined to near baseline values by the end of the 10 wk program (53). Some research has shown that basal total testosterone levels increase over baseline levels after as little as 7 wk of training in already trained subjects (6, 29).

Other studies have not demonstrated this training-related elevation in basal total testosterone concentrations. Craig et al. (24) found that in six younger males (mean = 23 y), although insignificant, basal testosterone concentrations decreased by 0.19 ng/mL (8.5 ± 0.6 ng/mL to 8.3 ± 0.7 ng/mL) following 12 wk of resistance training. In the same study, after an acute bout of weight lifting, total testosterone levels remained virtually unchanged for up to 15 min following exercise. Many studies looking at the effects of long term resistance exercise on hormonal response have found no change in total testosterone concentration compared to baseline values (42, 47, 53, 64).

Many factors affect basal total testosterone concentrations (age, body composition, training status, sex). Resistance training may have an effect on resting concentrations of total testosterone, however the research is still inconclusive. The intensity, volume and duration of a resistance training program may all play a role in changes in hormone concentrations.

Free testosterone is the active or "bioavailable" form of the hormone (58, 92). To date, the literature looking at changes in free testosterone with resistance training is inconclusive. While much of the research shows no change in basal concentrations of free testosterone after a long term resistance training program (17, 29, 42), some are in

disagreement. Kraemer et al. (53) determined that although there were no significant changes in resting total testosterone levels, serum free testosterone levels increased significantly (~20%) following 10 wk of resistance training. In another study, 16 wk of resistance training caused a trend for decreased basal free testosterone concentrations compared to baseline values (120 pmol/L to 113 pmol/L) in 21 trained younger men (4). These authors describe a training-induced increase in endogenous androgen turnover as an explanation for the drop in free testosterone levels for the older men. Izquierdo et al. (47) found that post-training resting free testosterone concentrations increased by 5.5% over pre-training levels in 11 untrained young men (46 ± 2 y). However, concentrations of this hormone tended to decrease in 11 untrained, older men (64 ± 2 y) following the same workout program. Most of the change occurred during the final 8 wk of training. Based on the little research available, it seems that a resistance training program may cause resting free testosterone levels to decline over time, however more studies are needed to confirm this.

Effects of resistance training on plasma IGF-1 concentrations

Although at least one study has shown a response in plasma IGF-1 concentrations to an acute bout of resistance exercise (60), most studies fail to show any change in resting IGF-1 concentrations following a 10 or 12 wk resistance training protocol in untrained men (8, 53, 60, 64, 94). However, one study showed a 20% increase in resting serum IGF-1 concentrations after 13 wk of resistance training in 31 men and women (13). Subjects trained 3 d/wk for 25 wk and were separated into either a one set or three set training group, both groups of subjects performing 8-12 RM for seven different exercises. By the end of the first 13 wk of training, subjects significantly increased circulating IGF-

1 levels (P = 0.041). Specifically, men increased IGF-1 levels by 29%-40% (1-set vs. 3-set, respectively) over baseline levels. There was no further increase during the second half of the training period.

It is known that a correlation exists between the release of IGF-1 and growth hormone, dietary intake (carbohydrate or protein) and insulin, and some research shows that endurance exercise may also regulate IGF-1 release (49). Fourteen swimmers were followed for 4 mo throughout the training period, which included both endurance and resistance exercises. After 2 mo, only modest increases in total IGF-1 were seen, but by the end of the 4 mo, resting total IGF-1 concentrations increased 76% and resting free IGF-1 concentrations increased 77-102%. They concluded that a relatively long-term endurance training program caused the drastic increases in IGF-1 concentrations.

In another study, after 3 d of nutritional supplementation with 33% protein and 67% carbohydrate, consumed 2 h before and immediately after exercise, pre-exercise IGF-1 levels were significantly higher for the supplemented group (~31 nmol/L vs. ~32 nmol/L, respectively) than pre-exercise values for the placebo group (~23.5 nmol/L vs. ~26 nmol/L, respectively) on d 2 and 3 (55). Therefore, the increase in IGF-1 levels must have been a result of supplementation instead of resistance exercise. Svanberg et al. (77) found that during starvation, skeletal muscle IGF-1 mRNA expression was depressed, however, upon refeeding, normalized. This suggests that oral feeding stimulates muscle IGF-1 production. These studies show that dietary intake plays an integral role in changes in circulating levels of IGF-1 independent of exercise.

However, Gater et al. (38) found that resting IGF-1 concentrations were significantly higher among subjects who consumed a placebo compared to subjects who

consumed an amino acid supplement following 10 wk of resistance training. In this study, subjects were assigned to consume a placebo (PL), mixed amino acid supplement (AA: 66 mg arginine and 66 mg lysine) or a mixed dietary supplement (EX: Exceed) in combination with a 10 wk resistance training program. Basal IGF-1 concentrations significantly increased in the PL group (20.5±3.0 pmol/L to 23.2±2.5 pmol/L), significantly decreased in EX group (25.0±4.8 pmol/L to 22.0±4.0 pmol/L) and did not change in the AA group (14.8±1.5 pmol/L to 15.0±4.0 pmol/L) from baseline levels. Therefore, although these results show an increase in resting IGF-1 concentrations in response to a long term resistance exercise program, they fail to show a relationship between the hormone and dietary intake.

Like insulin, while most studies cannot prove a relationship between long term resistance training and changes in resting IGF-1 levels, research shows that exercise and diet are two factors contributing to acute changes in plasma concentrations of IGF-1. Over a longer period of time, dietary supplementation and resistance exercise may result in increases in basal IGF-1 concentrations.

Role of insulin on muscle protein deposition

The exact role of insulin as a regulator of protein metabolism is not yet fully understood. The majority of the research agrees that insulin has an anabolic effect on muscle protein, however, it is not known whether insulin works specifically to promote muscle protein synthesis, inhibit muscle protein degradation, accelerate amino acid transport or a combination of these effects. Biolo et al. (9) infused insulin into the femoral artery of their six male subjects. While insulin infusion caused a 65% increase in muscle protein fractional synthesis rate, it also led to a decrease in the intracellular

concentrations of all essential amino acids and had no significant effect on protein degradation. Insulin infusion led to a shift in net protein balance, from a net negative balance in the post-absorptive state to a net positive balance after the infusion. These results indicate that during the post-absorptive state, while insulin stimulated muscle protein synthesis, its effects on protein degradation and amino acid transport were not sufficient enough to account for the increased utilization of intracellular amino acids, therefore posing a self-limitation on protein synthesis. A number of studies show that even without increased insulin concentrations, protein breakdown can be diminished by up to 20-30% (21, 37, 73, 79). However, by reducing protein breakdown, insulin may also limit the availability of substrate (amino acids) and therefore decrease the rate of muscle protein synthesis as well.

Bennet et al. (7) infused insulin and amino acids into the leg of their eight human subjects to determine the effects on local and whole body protein metabolism. With insulin infusion, leg and whole body protein balance increased to become more positive over amino acid infusion alone ($P<0.001$). Specifically, phenylalanine $R_{a,}$ an indicator of protein breakdown, decreased 9% during insulin infusion and phenylalanine $R_{d,}$ an indicator of protein synthesis, increased 55% during insulin infusion. This study shows that insulin, along with the presence of amino acids, promotes whole body protein synthesis and reduces the rate of whole body protein degradation. Another study showed that without the availability of amino acids, the suppressive effects of insulin on protein degradation were blunted, however, with normal levels of plasma amino acids, the ability of insulin to inhibit protein breakdown was enhanced (31).

Some researchers use insulin infusion along with resistance exercise to determine the combined effect on muscle protein metabolism. In a follow up study, Biolo et al. (11) found that insulin infusion following exercise had no effect on either amino acid transport or muscle protein synthesis, but significantly decreased muscle protein degradation in five untrained males. They concluded that the reduced availability of amino acids, resulting from the decreased rate of protein breakdown limited the ability of insulin to promote muscle protein synthesis.

In summary, the research shows that insulin has an anabolic effect in the muscle, however it is not clear whether its primary role is to increase protein synthesis, reduce protein degradation or stimulate amino acid transport. It is possible that insulin works to promote a combination of all three mechanisms in order to achieve positive muscle protein balance.

Role of testosterone on muscle protein deposition

Testosterone is known to promote muscle protein synthesis (12, 32, 33). In one study, seven men were followed before and 5 d after a 200 mg injection of testosterone enanthate in the fasted state (30). Testosterone levels were still elevated above baseline values 5 d following the injection. Fractional synthesis rate increased by almost 2% per day, while there was less than a 1% increase in fractional breakdown rate, and no change in amino acid transport following the injection. These results indicate that testosterone promotes protein synthesis not through increased transport of amino acids through the blood, rather through reutilization from protein breakdown back into protein. The increase in protein synthesis, it can be assumed, will lead to increases in lean tissue. In another study, nine normal males were administered 3 mg/kg/wk of testosterone for 12

wk to determine its effect on muscle mass (40). The results showed a 5 kg increase in body weight, along with a mean 27% increase in muscle protein synthesis due to the testosterone administration. Also, LBM, assessed by total body potassium, increased by 12%. Although muscle protein breakdown was not measured in this study, the authors hypothesized that there must have been a significant increase; otherwise, LBM would have increased more substantially due to the large increase in the rate of muscle protein synthesis. Additionally, subjects given weekly injections of testosterone for 12 wk increased LBM by 7.5 kg, or 12%, and decreased BF by 3.4 kg, or 27% of the baseline measurement (34). Therefore, the research shows that without resistance exercise, increased testosterone concentrations may lead to increased muscle protein synthesis, which may result in increases in lean body mass.

Studies show that with age, testosterone concentrations gradually decline. Due to the reduced level of this hormone, percent body fat increases and the percentage of lean body mass decreases. To prevent this change in body composition, researchers are now focusing on the effects of testosterone treatment in some older individuals. Snyder et al. (74) found that in men aged 65 y and older, 4-6 mg/d of testosterone led to a significant reduction in body fat (-2.9 ± 0.5 kg) and a significant increase in lean body mass (+1.9 ± 0.3 kg) after 36 mo of treatment. In a similar study, six elderly men (67 ± 2 y) were administered testosterone so that their serum levels were equal to those of younger men (85). After 4 wk, work per repetition in the quadriceps and hamstrings significantly increased, indicating an increase in muscle strength. These studies show that over a long period of time, increased testosterone levels in elderly men may lead to increased muscle strength and improved body composition.

Long term resistance exercise may increase serum testosterone concentrations, which, as the research shows, leads to increases in protein synthesis. Other studies have shown that increased testosterone levels, through testosterone administration, over time may improve body composition and muscle strength.

Total testosterone has a larger molecular weight than free testosterone and cannot cross capillary cell walls or penetrate the plasma membrane. Instead, it regulates free testosterone, the marker of "bioactivity status" (53).

There is limited research looking at serum free testosterone concentrations in young men. One study found that in elderly men, free testosterone was directly related with fat mass, lean mass, bone mineral density and muscle strength, however, was not related with isometric grip strength (86). Another study showed a trend for correlation between free testosterone levels and maximal isometric force in already resistance trained younger men ($r = 0.60$) (4). Izquierdo et al. (47) showed that after 16 wk of training, changes in serum free testosterone concentrations were correlated with changes in maximal unilateral isometric force ($r = 0.5$) in both middle aged men and older men. The older men, whose serum free testosterone levels decreased below baseline in the final 8 wk of training, increased their maximal strength at a diminished absolute rate compared to the middle aged men. The results indicate that lower serum free testosterone levels may indicate a lower "bioactivity status" due to a training program that was too stressful for the older men during the last 8 wk of training.

Although plasma free testosterone levels appear to be correlated with changes in muscle strength and possibly body composition primarily in elderly men, more research

is needed to determine the mechanism behind this effect and other possible effects on muscle protein metabolism in untrained, younger men.

Role of insulin-like growth factor-1 (IGF-1) on muscle protein deposition

IGF-1 is a hormone that has been shown to have an anabolic effect on muscle protein (23, 51). The specific anabolic mechanism of action of IGF-1 in skeletal muscle is still unclear. Adams and Haddad (2) researched the time course of skeletal muscle hypertrophy and increased muscle IGF-1 peptide levels in both normal and hypophysectomized rats. They found that IGF-1 mRNA and peptide concentrations were elevated before significant muscle hypertrophy accumulation and remained elevated for 28 d during the hypertrophy process. The results also suggest a role for IGF-1 in muscle hypertrophy through a positive correlation with DNA concentrations in the target muscle.

Fryburg (36) investigated the effects of a 6 hr infusion of IGF-1 into the forearm of 19 normal adults on muscle metabolism. They found that IGF-1 infusion had an overall anabolic effect with a 70% increase in muscle protein synthesis, indexed by phenylalanine $R_{d,}$ and a 40% inhibition of muscle protein breakdown, indexed by phenylalanine R_a. In another study using female rats, 3 wk of IGF-1 infusion led to a 9% increase in whole muscle mass and a 22-47% increase in total muscle protein content, depending on dosage (0.9 ug/3 wk vs 1.9 ug/2 wk, respectively) (3). The results show that IGF-1 infusion causes muscle hypertrophy in the target tissue. Other studies agree, that muscle hypertrophy signals the expression of the IGF-1 gene (26), confirming the role of IGF-1 in muscle protein metabolism.

Although more human studies are needed to confirm, the current research shows that IGF-1 plays a significant role in muscle protein hypertrophy possibly through a connection with DNA or through control over muscle protein metabolism.

Resistance training and dietary intake

It is well known that participating in an exercise program increases energy requirement, but it is not yet understood whether exercise has an impact on energy intake and specific nutrient composition. Much of the research shows that people participating in regular aerobic activity have a greater calorie intake than less active people (5, 84). However, the research looking at changes in dietary intake during a resistance training program is limited. In one study, 13 men were selected to participate in a 4 d/wk resistance training program lasting 12 wk (15). Subjects completed a 3 d food record before, at wk 6, wk 7 and after the training period to determine energy and nutrient intake. There were no changes in energy, carbohydrate, fat or protein intake over the 12 wk period, although the training group had a significantly higher intake of carbohydrate and a significantly lower intake of fat compared to the control group at pretreatment testing. Tucker et al. (84) found that in 30 previously untrained females, after 12 wk of resistance training, percent dietary fat decreased progressively throughout the training program to below the 30% recommendation and total energy intake also declined, while percent dietary carbohydrate increased and percent dietary protein remained unchanged. Changes in total muscle strength were associated with changes in dietary intake. Specifically, with increasing strength, fat intake significantly decreased and carbohydrate intake significantly increased ($P<0.05$). It may be that those who were motivated to work the hardest and gain the most strength and body composition improvements were more

conscious about their diet as well. More research is needed to look at the effects of resistance exercise on dietary quality in untrained college-aged men.

Analysis of body composition with DEXA

There are many ways to measure body composition. Dual-energy X-ray absorptiometry (DEXA) is widely used to measure bone density, and has recently become a preferred tool in measuring body composition because of its unique ability to measure both total as well as regional body mass. Many studies prove DEXA's ability to detect changes in body composition from as little as 0.5 kg in LBM and as little as a 0.5% change in BF (1, 28, 39, 82). For example, Treuth et al. (82) used DEXA to determine muscle mass changes in older men after 16 wk of strength training. Total FFM gains of 2 kg and FM losses of 2 kg measured by DEXA were confirmed by hydrodensitomety, and measurements of changes in regional muscle mass were comparable between DEXA and MRI. However, one study showed that DEXA's accuracy in measuring FM and FFM may not be guaranteed. Following 52 wk of intensive resistance training, DEXA detected a 0.6 kg increase in FFM and a 0.2 kg reduction FM, while hydrostatic weighing, sometimes identified as the "gold standard" for measuring body composition, detected a 1.3 kg increase in FFM and a 0.8 kg reduction in FM in 40 post-menopausal women (63). Additionally, the authors also noted that anthropometry, bioelectric impedance and total body nitrogen and carbon also failed to detect any significant changes in soft tissue.

One unique property of DEXA as a tool for measuring body composition is its ability to measure regional changes. Wang et al. (89) compared regional measurements of skeletal muscle mass in the calves, thighs and forearms using DEXA with multiscan

computerized axial tomography (CT) in adult men with AIDS. Landmarks that defined the upper limits of the calf and thigh were the knee joint and symphysis caudal edge, respectively, and the landmarks used to identify the lower limits of the calf and thigh were the ankle and knee joint, respectively. The landmarks defining the forearm were the elbow (upper) and wrist (lower). The results showed that regional measurements determined by DEXA were highly correlated with regional measurements determined by CT. Nindl et al. (65) looked at regional and whole body composition changes in women using DEXA after 24 wk of endurance and resistance training. After the training period, of the 2.6 kg (-2.2%) of total body fat tissue lost, 1.1 kg were from the arm region (42%), and 1.2 kg were from the trunk region (46%). A total increase of 0.9 kg (2.2%) lean tissue was accrued during the 24 wk training period. Of this, 0.2 kg came from the trunk region (22%) and 0.7 kg from the leg region (78%). There was no detected change in lean body mass in the arm region. When compared to magnetic resonance imaging (MRI), DEXA measurements were highly correlated with MRI measurements for both percent FM lost ($r = .88$) and percent LBM gained ($r = .72$). DEXA is an accurate and valuable method for analyzing body composition due to its ability to detect regional body mass changes.

CHAPTER 3:

Journal Manuscript

Effects of a Dietary Milk or Carbohydrate Supplement with Resistance Training on Body Composition, Muscle Strength and Anabolic Hormones in Untrained Men

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ABSTRACT

Twenty untrained men (18-25 y) were assigned to consume either a milk supplement (MILK) or a carbohydrate-electrolyte supplement (CHO) immediately following each resistance workout during a 10 wk resistance training program. Subjects trained 3 d/wk beginning with an intensity of 55% 1-RM and progressing to 97% 1-RM by wk 10. Muscle strength (1-RM), body composition (DEXA) and resting, fasted concentrations of total and free testosterone and IGF-1 were measured pre- and post-training. CHO tended to reduce, while MILK increased body weight ($P = 0.10$). All subjects significantly reduced percent body fat (1.1%) and significantly increased lean body mass (1.21 kg) as a result of the resistance training with no significant differences between treatments. However, MILK tended to increase lean body mass ($P = 0.1$) more than CHO (1.6 and 0.8 kg, respectively). About 39% of lean mass gain for all subjects was in the leg region, while the arms accounted for about 28% of lean gain. Resistance training also caused a similar significant 44% increase in muscle strength for the seven exercises combined for both groups. Resting total and free testosterone concentrations significantly decreased from baseline values in both groups of subjects (16.7%, 11%, respectively), while resting insulin concentrations significantly increased in all subjects ($P<0.01$). There were no significant changes in resting, fasted IGF-1 concentrations. In summary, dietary supplementation with a MILK or CHO beverage immediately following resistance exercise resulted in similar changes in muscle strength and hormone concentrations following a 10 wk periodized resistance training program. MILK tended to increase body weight and lean body mass more so than CHO.

Keywords: carbohydrate, periodized resistance training, testosterone, insulin, IGF-1

INTRODUCTION

Research has shown a relationship between long term resistance training and muscle hypertrophy and increased muscle strength. The exact protocol that will maximize muscle gains has yet to be identified, however studies have shown that a program including 8-12 wk of resistance training with varying intensity and volume results in a 1.0-2.9 kg increase in lean body mass, a 0.2-3% reduction in body fat, and up to 50% increased muscle strength (1, 9-12, 17-19, 31, 35, 37, 38, 50, 54, 55, 58).

Some research suggests that dietary intake plays a significant role in muscle hypertrophy and increased muscle strength. Several studies demonstrate an increased protein requirement for individuals involved in a resistance training program. Tarnopolsky et al. (51) reported that resistance trainers required more protein (1.4 g/kg) compared to sedentary individuals (0.9 g/kg) in order to maintain nitrogen balance, while an excess of protein (2.4 g/kg) did not continue to improve nitrogen retention. Research such as this has prompted studies testing the effect of dietary supplements on muscle growth.

The goal of dietary supplementation with resistance training may be to increase caloric intake to compensate for the increased energy cost of synthesizing new muscle, however the specific macronutrient content of a dietary supplement may also be important in the control of muscle protein metabolism with resistance exercise. Several studies have found that with administration of amino acids immediately following a bout of weight lifting, muscle protein synthesis was significantly increased and nitrogen balance was more positive compared with a placebo (6, 52). Other research revealed that supplementation with carbohydrate immediately after a session of resistance exercise led

to enhanced protein balance by significantly reducing the rate of muscle protein breakdown and showing a tendency toward increased muscle protein synthesis (48). More recently, studies have focused on the effects of a combination supplement on muscle protein metabolism. It has been shown that consuming a supplement containing a mixture of protein, carbohydrate and fat or one with protein and carbohydrate following a bout of resistance exercise, results in significantly increased muscle protein synthesis (44, 47). Therefore, a dietary supplement combined with a long term resistance training program may lead to an overall positive nitrogen balance, which may result in increased lean tissue. Gater et al. (23) found that subjects supplemented a mixed nutrient supplement (EXCEED) in combination with a 10 wk resistance training program significantly increased body weight (5%) and lean body mass (6%) at the end of training. However, supplemented subjects had similar increases in muscle strength as placebo. In another study, consumption of a carbohydrate-protein-fat supplement during a 12 wk resistance training program resulted in a 2.2 kg increase in body weight and a 9% increase in the sum of six skinfolds in elderly subjects, while unsupplemented subjects decreased body weight by 1.6 kg and had no change in skinfold measurements (39). Again, there were no significant differences in muscular strength compared to placebo. These studies show that long term dietary supplementation in combination with resistance exercise may result in significantly greater increases in body weight and lean body mass, however the supplementation may have no added benefit on muscular performance. Currently, there are no studies comparing the effects of a protein-carbohydrate supplement with a carbohydrate supplement and long term resistance training on body composition and muscle strength.

Muscle hypertrophy and increased muscle strength resulting from long term resistance training may be influenced by changes in some hormones involved in muscle protein metabolism. Although many studies confirm that a single bout of weight lifting promotes an increase in plasma levels of insulin, IGF-1, and testosterone, the effect of chronic resistance exercise and changes in these basal hormone concentrations is still controversial (16, 25, 26, 29, 37, 41, 55). The intensity, volume and muscle groups involved with the exercise may determine the amount of hormonal regulation (30). Recent evidence also suggests that nutritional supplementation along with exercise may affect concentrations of these hormones. For example, a temporal response of testosterone concentrations has been reported as a result of nutritional supplementation with protein, carbohydrate or a combination of the two immediately following a bout of resistance exercise from 4 h to 3 d post exercise (16, 33). Insulin concentrations are also acutely increased when subjects are supplemented after weight lifting (33, 35). IGF-1, insulin and testosterone are known to have some control over protein balance during weight lifting (3, 7). Therefore, over a longer period of resistance training, changes in the basal concentrations of these hormones may promote an overall positive state of protein balance, which may result in increased muscle growth and strength.

The purpose of this investigation was to determine whether a protein-carbohydrate dietary supplement consumed immediately following workouts will promote significant changes in specific anabolic basal hormone levels and therefore result in more muscle hypertrophy and gains in muscle strength than a carbohydrate dietary supplement following 10 wk of resistance training.

METHODS

Subjects

Twenty-one untrained male subjects between the ages of 18 and 25 y volunteered to participate in a 10 wk training study. Only subjects who were not involved in a resistance training program and were not taking any nutritional supplements for at least 3 mo prior to the start of the study were eligible for participation. Subjects gave their informed consent and were screened for contraindications to strenuous resistance exercise (muscular-skeletal injuries, medical conditions), food allergies and intolerances and muscle biopsies (lidocaine allergy) (Appendix C). The Institutional Review Board of Virginia Polytechnic Institute and State University approved all methods and procedures (Appendix D). Of the original 21 subjects, two who dropped out of the study due to medical reasons are not included in the final data analysis, making the final sample size 19 subjects.

Experimental Design

Before baseline testing, subjects completed a food frequency form to determine usual dairy intake (Appendix E). Subjects were then assigned to either a carbohydrate group (CHO) or a milk group (MILK) so that each group had a similar dairy intake and so that each group had similar mean body weight. Baseline testing was performed before any supplementation and training, and included strength assessment, body composition, blood collection and 3-d food records (Appendix A, B, F). After baseline testing, subjects began their 10 wk resistance training program. Both groups completed the same periodized resistance exercise training program. Immediately following each workout, subjects consumed an isocaloric dietary supplement of either a carbohydrate-electrolyte

beverage (Gatorade; Barrington IL) or low fat chocolate milk. Subjects were instructed to maintain their usual diet and activity level and not to begin other nutritional supplementation or outside exercise programs. Personal trainers supervised each workout.

Experimental Procedures

Before the start of baseline testing, subjects were instructed by a registered dietitian and were provided with specific verbal and written instructions and procedures for reporting dietary intake. Subjects completed 3 d food diaries at intervals throughout the study (0, 3, 6, 10 wks) in order to assess total energy, macronutrient (carbohydrate, protein and fat) and micronutrient (calcium) content using Food Processor, version 7.60 nutrient analysis software (ESHA Research; Salem, OR).

Body weight and height were measured upon arrival to the laboratory after a 12 h fast for pre-testing and post-testing. Weight was measured to the nearest 0.1 kg using a digital scale and height to the nearest 0.1 in. Muscle circumference measurements were taken as the average of duplicate measurements at the mid-thigh and mid-upper arm following American College of Sports Medicine guidelines (46) and on the chest at the level of the fourth costosternal joints, in the horizontal plane (15) and rounded to the nearest 0.1 cm.

Body composition (fat mass and fat free mass) was measured using DEXA (dual energy x-ray absorptiometry) with a Hologic QDR4500A. Subjects arrived in a fasted state and were told to lie on the table in a supine position. All metal objects (clothes, jewelry) were removed before testing. After the whole body scan was completed, regions of interest (upper arms, forearms, upper legs, lower legs) were measured by manual

DEXA analysis software. The DEXA was calibrated with tissue phantoms prior to each measurement.

Performance testing included assessment of one-repetition maximum (1-RM) leg press, leg curl, leg extension, bench press, shoulder press, lateral pull down and arm curl. All exercise testing protocols were performed using Body Masters equipment (Body Masters Sports Industries; Rayne, LA). After a warm-up with a light resistance that allowed 10 repetitions, subjects were given a 1-min rest period. Resistance was increased to allow 3-5 repetitions and then subjects were given a 2-min rest period. For each following trial, resistance was adjusted so that the subject could complete only 1 repetition with a 2-min rest period in between each trial. Add-on weights (2.3 kg, 1.1 kg, 0.45 kg) were used to get more accurate measurements.

Fasting blood samples were taken just prior to and at the end of the 10 wk training period for analysis of insulin, IGF-1, free and total testosterone. Insulin, free and total testosterone were all analyzed in duplicate using Coat-a-Count Radioimmunoassay (RIA) kits (Diagnostic Products Corp.; Los Angeles, CA) with intra-assay CV of 12.3%, 6.5% and 7.2% respectively. IGF-1 was analyzed using RIA as described in the study by Weber et al. (56) with an intra-assay CV of 6.7%.

Exercise Training

Resistance training sessions consisted of periodized workouts using the same exercise machines used for 1-RM measurements, and were supervised by qualified personal trainers, who rotated among subjects. The primary goals of the resistance training program were to increase muscle strength and muscle size. The training program included 3 d/wk for 10 wk. Exercises included leg press, leg curl, leg extension, bench

press, shoulder press, lateral pull down, arm curl and abdominals. Each exercise was performed at every workout session (Table 1).

Training intensity for the resistance training program was determined using the subjects' 1-RMs. Another strength assessment was completed at wk five and the intensity for the remainder of the study was based on these new 1-RMs. Subject training logs were maintained throughout the 10 wk experimental period detailing the exercises, intensities, sets and repetitions performed (Appendix F). Subject compliance to training sessions was 94.4%. Extra incentives, which were announced after baseline testing, were offered to the subjects based on strength gain and attendance.

Nutritional Supplementation

The supplement given to the CHO group provided 5 kcals/kg body weight, 1.25 g/kg carbohydrate and electrolytes. The supplement given to the MILK, low fat chocolate milk, provided 5 kcal/kg body weight, 0.92 g/kg carbohydrate, 0.21 g/kg protein, 0.06 g/kg fat and vitamins and minerals. Volume of the carbohydrate beverage was determined by subject preference (powder mixed with water). Beverages were served cold by the experimenters or personal trainers and were consumed shortly following each workout (mean: 3.25 min). As the experimenters observed the beverage consumption, subject compliance to beverage consumption was 100%. During the first week of training, five subjects complained of nausea/vomiting immediately following consumption of the drink. No distress was reported after the first week of the experimental period.

Statistical Analysis

Statistical evaluation of the data was accomplished by using a two-way analysis of variance (ANOVA) with repeated measures design to test for effect of group, time and group by time interaction. A t-test was performed to detect differences between treatments in body composition, and correlation analysis was used to determine any relationships between measurements. The level of significance was set at $P \leq 0.05$.

RESULTS

Anthropometrics

Initial physical characteristics of the subjects are presented in Table 2. There were no statistical differences among groups for any of the listed variables prior to the treatment period. Body weight increased by about 1 kg in the milk treatment group and decreased by the same amount in the CHO group following the 10 wk training period. Results of a t-test analyzing the difference in change in body weight between treatments revealed P=0.10. Girth measurements taken before and after testing are presented in table 3. Right and left arm muscle circumference significantly increased in both groups from baseline measurements (P<0.05). There was a trend toward increased right leg (P=0.10), left leg (P= 0.08) and chest (P=0.07) muscle circumference in both treatment groups at wk 10. However, there were no differences in circumferences by treatment group.

Body Composition

There were no significant differences between groups at baseline for whole or regional body composition (Tables 2, 4, 5). By the end of the 10 wk training period, all subjects significantly reduced total body percent body fat (P<0.05) and significantly

increased total lean body mass (P<0.01) from baseline. There were no significant differences in either measurement between treatment groups, although a t-test revealed the MILK group (2.6 kg) tended to increase lean body mass (P=0.13) more than CHO (0.8 kg). The average decrease in percent fat for CHO group (1.4%) was more than for MILK (0.9%), although this difference was not significant. Figure 1 shows the change in body composition measurements from pre to post testing.

Of the 0.9% (0.6 kg) reduction in body fat in the MILK group, 0.23 kg came from the leg region, 0.05 kg was lost from the arms and the rest (0.22 kg) from the trunk. The CHO group reduced percent body fat by 1.4% (1.31 kg): 0.39 kg from the legs, 0.18 kg from the arms and 0.67 kg from the trunk. Also, all subjects significantly reduced absolute body fat in right total leg, right upper leg and left total arm (P<0.05) and showed a trend for decreased absolute body fat in the left upper arm (P=0.06), right upper arm (P=0.07), left forearm (P=0.06) and left lower leg (P=0.07). The MILK group increased lean body mass by 1.6 kg, of which 0.73 kg increased in the leg region, 0.39 kg in the arm region and 0.53 kg in the trunk. Of the 0.8 kg increase in lean body mass in the CHO group, 0.29 kg was in the leg region, 0.10 kg in the arms and 0.67 in the trunk region. For both treatments, left total arm, left upper arm, right upper arm, left total leg, right total leg, left upper leg and right upper leg lean body mass significantly increased by the end of the 10 wks (P<0.05), while right total arm lean body mass showed a tendency for increased lean body mass (P=0.06).

Strength

Muscle strength for any of the seven exercises was not significantly different between groups prior to training (Table 6). All subjects, independent of treatment,

significantly increased muscle strength at the end of the 10 wk training period for each of the seven exercises ($P<0.001$). Leg press 1-RM increased by 26-229%, and bench press 1-RM increased by 14-50% after 10 wks of training. Whole body muscle strength was calculated as the percentage increase in 1 RM when summing all seven exercises. Whole body muscle strength significantly increased similarly in subjects given CHO and MILK supplementation from pre- to post training. There was no correlation between changes in body composition and changes in muscle strength. Figure 2 demonstrates the change in overall muscle strength during the 10 wks.

Hormones

Serum resting hormone concentrations were not significantly different between treatments before the start of training (Table 7). Both treatment groups saw a significant reduction from baseline in basal concentrations of both free testosterone (CHO: 14%, MILK: 8%) and total testosterone (CHO: 18%, MILK: 15%).

One subject had a fasting insulin more than two standard deviations away from the mean (assumption is that he failed to fast) after training, therefore his data were removed from the insulin analysis. Therefore, with only 18 subjects, resting insulin concentrations significantly increased ($P<0.01$) over baseline values in both groups. There were no significant differences between treatment groups. Morning serum concentrations of IGF-1 were not altered by training and supplementation with CHO or supplementation with MILK. There were no correlations between hormone concentrations and changes in either body composition or muscle strength.

Dietary Intake

Subjects completed a dairy food frequency form prior to the start of the study. CHO subjects consumed 76.2±15.2 servings of dairy per month and MILK subjects consumed 81.4±13.7 servings. Of the original 19 subjects, the final dietary analysis includes 17 due to one subject not complying with this request to keep a food diary and another subject's dietary intake included many combination foods that could not be identified by the subject. Dietary intake was not significantly different between the CHO and MILK supplemented groups before the training period (Table 8). There were no significant differences in calorie intake, percent carbohydrate, protein or fat intake at any time between groups, however there was a trend for increased calcium intake over time in all subjects (P=0.06). Protein intake was similar for the CHO group and the MILK group before and after training (1.2 g/kg). There were no correlations between dietary intake and changes in hormone concentrations, body composition or muscle strength.

DISCUSSION

The results of this study indicate that supplementation with either a carbohydrate beverage or a milk beverage promotes increased muscle strength similarly, however MILK supplementation showed a trend toward increased body weight and lean body mass. Additionally, 10 wk of resistance training, with no further effects from nutritional supplementation, caused a significant reduction in basal free and total testosterone concentrations and a significant increase in resting insulin concentrations.

Body weight and composition

Subjects tended to increase body weight during the 10 wk training period when consuming a MILK supplement compared to CHO. However, this change in body

weight was not associated with changes in dietary intake. Other research has shown that when nutritional supplementation affects dietary quality or quantity, body weight is also usually affected (23, 39). For example, subjects who consumed a mixed macronutrient supplement, which was designed to promote a 2.2 kg/wk increase in body weight, consumed significantly more calories and increased body weight significantly more than the placebo (39). Therefore, it is likely that an increase in energy intake is more important than specific macronutrient content of a dietary supplement in the promotion of increased body weight. Weight change may also occur due to a change in energy expenditure, which was not measured in this study. However, because the training protocol was the same for all subjects, its effects on body weight would be expected to be similar.

Our findings of a significant increase in arm circumference and a trend for increased chest and leg circumference is supported by at least one other study (18). Cureton et al. (18) showed that while 16 wk of resistance training did not promote significant changes in thigh muscle hypertrophy, there was a significant increase in upper arm circumference (7.9%). The reason for the substantial upper arm muscle hypertrophy in this study compared to our study (2.1%) is that subjects performed various exercises that concentrate on the upper arm muscles, whereas in the current study, subjects performed only one arm exercise (arm curl). Also, in our study, it may be that the decrease in body fat (5%) in the leg region offset the increase in LBM (2.5%), and therefore resulted in only a statistical trend for an increase in thigh circumference.

Although other studies incorporating a 12 wk periodized resistance training program with young males have observed similar increases in lean body mass, many have

seen an increase in percent body fat as well (38, 55). For example, Volek et al. (55) observed a 2.1 kg increase in LBM, along with a 0.9 kg increase in absolute body fat, and Mazzetti et al. (38) showed that subjects gained 1.4 kg in LBM and also increased percent body fat by 2.1% following a 12 wk periodized resistance training program. The differences in results are likely due to the pretraining status of the subjects. Our subjects, who had not recently participated in any form of organized exercise, significantly reduced percent body fat. Many other studies show that a long term resistance training protocol results in up to a 2.8% loss in body fat in previously untrained men (11, 12, 18, 50, 59). Therefore, it appears that previously untrained young men significantly increase lean body mass and significantly reduce body fat after just 10 wk of a periodized resistance training program.

Using DEXA to measure body composition allowed us to also observe changes in regional body composition. Our results show that both supplements promoted similar significant improvements in arm and leg body composition measurements (Table 3), however we observed greater changes in leg body composition compared to arm body composition. To our knowledge, there are no other studies looking at changes in regional body composition in young males following a resistance training program. However, some studies have observed these changes in other subject populations (41, 54). In one study, women who performed endurance and resistance training for 24 wk lost a total of 2.6 kg in body fat, 42% (1.1 kg) of which came from the arms and 46% (1.2 kg) from the trunk area, and gained 0.9 kg in lean tissue, 78% (0.7 kg) of which came from the legs and 22% (0.2 kg) from the trunk region (41). The women showed no change in lean tissue in the arm region and no change in body fat in the leg region. Treuth et al. (54)

observed a 10.5% and 8% reduction in fat mass in the arms and legs, respectively, and a 6% and 4% increase in fat free mass in the arms and legs, respectively, following a 16 wk resistance training program in older men. It is difficult to directly compare these studies due to the different genders and age of subjects. However, our results show that 10 wk of periodized resistance training is sufficient to observe significant changes in regional body composition measurements in untrained young men, and that the majority of the change in lean body mass and body fat came from the leg region.

Nutritional supplementation with either CHO or MILK after each training session appeared to result in similar losses in fat mass, however MILK tended to increase lean body mass more than CHO. Some research suggests that during resistance training, increased calorie intake, not specific macronutrient content, is more important for improving body composition (14, 15, 23, 39). For example, Gater et al. (23) found that supplementation with a mixed macronutrient beverage, which resulted in an increased energy intake, led to a significant reduction in percent body fat (0.6%) and a significant increase in LBM (3.6 kg) from pretraining, while consumption of a placebo induced a 1% reduction in percent body fat and a 2.1 kg increase in LBM. Other studies looking at the effects of supplementation in the elderly have shown that dietary supplements designed to increase overall caloric intake, consumed in addition to a long term resistance program, improved body composition and nitrogen retention (14, 15, 39), suggesting that the extra calorie consumption promotes nitrogen retention by sparing the amount of energy gained from protein degradation. Few studies have tried to separate the effect of total energy intake from consumption of specific nutrients.

Although in the present study neither supplement had any effect on calorie or nutrient intake during the training program, MILK supplementation led to a trend for increased LBM (1.6 kg vs. 0.8 kg) compared to the CHO supplement. If more protein was included in the MILK supplement, we may have observed a more significant increase in LBM. Meredith et al. (39) found that a dietary supplement increased overall protein intake (1.2 g/kg to 1.6 g/kg) during the 12 wk training program in their elderly subjects. Supplementation also led to a significant increase in mid-thigh muscle area, which was shown to correlate with the increase in protein intake (r=0.63). Another study which compared a 1.5 g/kg carbohydrate supplement to a 1.5 g/kg protein supplement along with an intensive 1 mo training program found similar improvements in muscle size and strength with both supplements, however the protein supplement promoted a significantly more positive nitrogen balance compared to the carbohydrate supplement (35). Although this higher nitrogen retention was not accompanied by greater muscle function gains in those consuming a protein supplement, this suggests that over time, supplementation with 1.5 g/kg protein may lead to greater increases in muscle size and strength than a carbohydrate supplement. Our study did not assess nitrogen balance, but we did find that supplementation with a protein-carbohydrate supplement did not increase overall dietary protein intake (1.2 g/kg), however led to a trend for more accretion of lean tissue during resistance training than a carbohydrate supplement. It is possible that a supplement with a higher protein content would have caused significantly greater muscle hypertrophy and increased strength gain.

To date, there are no other studies comparing the effects of a carbohydrate-protein with a carbohydrate dietary supplement in addition to a long term resistance training on

body composition and muscle strength. However, one study showed that with an acute bout of resistance exercise, a supplement including carbohydrate, protein and fat consumed immediately and 1 h following the workout led to a 41% increase in protein synthesis with no effect on protein breakdown 4 h after training (47). Similarly, Rasmussen et al. (44) found that subjects who consumed a carbohydrate-amino acid supplement 1 or 3 h following the workout significantly increased protein synthesis but the supplement had no effect on protein degradation 4 h following exercise. These studies suggest that supplementation with a mixed macronutrient beverage may benefit muscle protein balance, which could maximize gains in lean tissue over a longer period of resistance training. Although it is difficult to speculate since we did not measure protein metabolism, it is possible that the acute increase in protein synthesis following consumption of the supplement and a bout of resistance exercise, as observed in previous studies (44, 47), did not lead to a permanent increase in protein balance.

Muscular Strength

The 44% increase in overall muscle strength is larger than what most other studies looking at the effects of resistance training on muscle strength following 8 to 10 wk of training found (15-50%) (1, 10, 12, 18, 19, 36, 38, 55, 59). Differences in training protocols may be an important factor in explaining the greater increase in muscle strength found in the present study compared to some others. One study observed only a 25% increase in overall muscle strength as 30 active men performed 13 upper and lower body exercises using a combination of free weights and machines 3 d/wk for 10 wk at 10-12 RM for the first set, 8-10 RM for the second set and 4-8 RM for the third set. While this protocol adjusted intensity and volume with each set, our training protocol increased load

and reduced volume by the week. Periodized weight training has been reported to produce superior strength gains, even over the short term, compared to other forms of resistance training (51). Our protocol was similar to that of Mazzetti et al. (38) and Volek et al. (55), who observed a 25% and 16% increase in 1-RM bench press in previously trained subjects after a 12 wk periodized training program, while our subjects increased 1-RM bench press by 30% after just 10 wk. The discrepancy in strength gains between the previous studies that incorporated periodized resistance training (38, 55) and the present may likely be due to our subjects not being previously trained. Strength gains are likely to be greater in untrained subjects because of the enhanced potential for muscle adaptation (32). Additionally, because our study did not include a control group, we cannot determine whether the addition of dietary supplementation promoted the greater increase in overall muscle strength. However, Gater et al. (23) found that subjects who consumed a dietary supplement had a similar increase in muscular strength as subjects who consumed a placebo, indicating that resistance training was more important than dietary supplementation for increasing strength. Therefore, it is likely that our large muscular strength gains were due to the initial training status of our subjects as well as the periodized training program they followed.

Hormones

Resistance training caused a significant reduction in resting total testosterone (16.5%) and free testosterone (10.5%) concentrations from pre- to post-training with no significant difference between treatments. Fry et al. (21) observed a significant decrease in serum total testosterone concentrations (resting, immediately pre-exercise, 5 min and 15 min post-exercise) after 1 wk of intensive weight training. It is possible that these

results are due to such a large increase in training volume, which may suggest overtraining. Overtraining is indicated by an increase in training volume or intensity that results in reduced performance or a plateau of strength gains (21, 43). It is possible that the training program we used initiated signs of overtraining, which may have limited optimal gains in LBM. Measurement of serum cortisol would have been useful to determine existence of the overtraining syndrome. An alternative explanation for the decline in resting testosterone concentrations could be a training-induced increase in androgen turnover. Exercise-induced changes in testosterone clearance and production rates have been observed in other studies (13).

There is research that supports an increase in resting testosterone concentrations in response to resistance training, in contrast to the results of the present study. Staron et al. (50) showed that basal total testosterone concentrations increased 30% over baseline following just 4 wks of training and remained elevated throughout the 8 wk training period. Another study showed that while basal total testosterone concentrations increased 15% after 3 wk of resistance training, concentrations returned to baseline levels by the 10^{th} wk of training (33). In the same study, basal concentrations of free testosterone were significantly increased ($P<0.01$) after 10 wk of training in previously untrained men, and in another study, a 16 wk training program caused a trend for increased resting free testosterone concentrations in untrained middle-aged men (2). Other studies have observed no change in basal testosterone concentrations following a long term resistance training program (17, 20, 42). Therefore, it appears that resistance training may have a temporal effect on resting testosterone concentrations to an increase during the first

weeks of training, but falling to or below baseline levels over time. Validity of this theory would require additional blood samples over the course of resistance training.

Other hormones, such as insulin and IGF-1, have been associated with maintenance of protein balance along with a weight lifting program, although the mechanism behind hormonal control of protein metabolism is not yet clear (3, 7). In the present study, all subjects significantly increased resting insulin concentrations from pre- to post-training. These results were unexpected, as other studies have failed to show any change in resting insulin concentrations following a long term resistance training program (33, 59). Therefore, increased resting insulin concentrations may help explain the mechanism behind the increased lean body mass and muscle strength observed following the 10 wk training program.

The lack of change in resting IGF-1 concentrations in response to a 10 wk resistance training program is in agreement with much of the research (4, 31, 37, 40, 59). In contrast however, Gater et al. (23) observed a significant increase in resting IGF-1 concentrations in response to resistance exercise alone, while subjects consuming a mixed nutrient supplement significantly reduced resting IGF-1 concentrations. It has been suggested that specific dietary content plays an important role in the control of circulating IGF-1 concentrations (45, 49). Therefore, the lack of change in basal IGF-1 concentrations observed in the present study is likely explained by the fact that subjects maintained a consistent dietary intake throughout the 10 wk period. There is a possibility that locally produced IGF-1 changed due to training. Measurements of mRNA for IGF-1 in muscle tissue would be necessary to resolve this issue.

Dietary Intake

There were no significant changes in dietary quality or quantity during the experimental period for either treatment group. While Gater et al. (23) showed that calorie intake remained isocaloric throughout the study regardless of supplementation, total dietary protein intake was significantly higher in trained subjects who consumed or a mixed nutrient supplement (1.44 g/kg) compared to untrained subjects who consumed a placebo (0.85 g/kg). In the current study, all subjects were slightly below the current recommendations for protein intake for individuals participating in resistance exercise throughout the 10 wk (1.25 g/kg). Tarnopolsky et al. (51) determined that for strength-trained subjects to maintain a positive state of nitrogen balance, a protein intake of 1.4 g/kg is recommended, and the latest recommendation for increasing muscle size and strength with resistance training is to consume 1.6 to 2.0 g/kg (34). All subjects showed a trend for increased calcium intake from pre to post training with no difference between treatments. Subjects' were instructed to keep a food diary on one weekend day and two weekdays. Therefore, only one day in each food diary reflected dietary intake with the supplement. If the food record had reflected one week of dietary intake, it would have included three days of supplementation, and may provide a more accurate indication of the effect of supplementation on dietary quality and quantity.

CONCLUSION

A 10 wk periodized resistance training program led to significant muscle hypertrophy and gains in muscular strength. Supplementation with MILK resulted in a tendency for increased LBM and body weight compared to supplementation with CHO. All subjects experienced similar reductions in basal concentrations of free and total

testosterone and increased insulin concentrations in response to the 10 wk resistance exercise program. Thus, nutritional supplementation with either milk or a carbohydrate-electrolyte beverage appeared to have no significant effect on body composition, muscular strength or endocrine function following a 10 wk resistance training program.

This research was funded by the National Dairy Council. Researchers would like to thank Janet Rinehart for laboratory assistance and for performing blood draws. Randy Bird and Michael Puglisi assisted with data collection and analysis.

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Table 1. Periodized Resistance Training Protocol

WEEK	SETS	REPETITIONS	INTENSITY (% 1 RM)
1	3	12	55
2	4	10	64
3	4	10	67
4	4	8	70
5	4	6	73
6	4	6	76
7	5	5	82
8	5	5	85
9	3	3	94
10	3	3	97

Table 2. Subject characteristics and body composition before and after 10 wk of training

	Age	**Ht (cm)**	**Wt-pre (kg)**	**Wt-post (kg)**	**LBM - pre (kg)**	**LBM-post (kg) ****	**BF-pre (%)**	**BF-post (%) ***	**BF-pre (kg)**	**BF-post (kg)**	**Trunk LBM-pre (kg)**	**Trunk LBM-post (kg)**	**Trunk BF-pre (kg)**	**Trunk BF-post (kg)**
CHO	21.0 (0.47)	175.3 (3.0)	79.8 (4.9)	78.9 (4.3)	60.9 (2.9)	61.7 (2.4)	20.3 (1.5)	18.9 (1.4)	16.8 (2.2)	15.5 (2.0)	28.73 (1.40)	29.40 (1.22)	7.03 (1.10)	6.36 (1.03)
MILK	20.5 (0.62)	179.7 (2.0)	78.0 (5.2)	78.9 (5.1)	61.0 (2.8)	62.6 (2.9)	17.9 (2.1)	17.0 (1.9)	14.9 (2.7)	14.3 (2.1)	28.99 (1.07)	29.52 (1.20)	5.34 (0.93)	5.12 (0.87)

Values are averages with SEM in parentheses

* indicates significant change for groups combined from pre to post training ($P<0.05$)

** indicates significant change for groups combined from pre to post training ($P<0.01$)

Table 3. Muscle circumference measurements before and after 10 wk of resistance training

	Chest-pre (cm)	**Chest-post (cm)**	**Right Arm-pre (cm)**	**Right Arm-post (cm) ***	**Left Arm-pre (cm)**	**Left Arm-post (cm) ***	**Right Leg-pre (cm)**	**Right Leg-post (cm)**	**Left Leg-pre (cm)**	**Left Leg-post (cm)**
CHO	96.4 (3.1)	97.1 (2.6)	32.7 (1.6)	33.4 (1.2)	32.1 (1.6)	32.6 (1.3)	56.4 (2.0)	56.6 (1.7)	56.4 (1.8)	56.7 (1.7)
MILK	94.4 (2.0)	96.6 (2.6)	31.4 (1.2)	31.9 (1.2)	30.7 (1.3)	31.6 (1.2)	55.1 (2.0)	56.2 (2.2)	55.0 (2.0)	56.1 (2.3)

Values are averages with SEM in parentheses

* indicates significant change for groups combined from pre to post training ($P<0.05$)

Table 4. Arm body composition measurements before and after 10 wk of resistance training

	Left Total LBM (kg) - pre	**Left Total LBM (kg) - post ****	**Right Total LBM (kg) - pre**	**Right Total LBM (kg) - post**	**Left Forearm LBM (kg) - pre**	**Left Forearm LBM (kg) - post**	**Right Forearm LBM (kg) - pre**	**Right Forearm LBM (kg) - post**	**Left Upper LBM (kg) - pre**	**Left Upper LBM (kg) - post ***	**Right Upper LBM (kg) - pre**	**Right Upper LBM (kg) - post ***
CHO	3.62 (0.22)	3.69 (0.18)	3.82 (0.24)	3.85 (0.16)	1.44 (0.07)	1.46 (0.07)	1.49 (0.08)	1.50 (0.05)	2.17 (0.16)	2.23 (0.12)	2.32 (0.16)	2.35 (0.12)
MILK	3.51 (0.21)	3.72 (0.23)	3.69 (0.17)	3.87 (0.18)	1.44 (0.07)	1.49 (0.08)	1.52 (0.07)	1.55 (0.06)	2.08 (0.15)	2.23 (0.16)	2.17 (0.11)	2.32 (0.13)

	Left Total BF (kg) - pre	**Left Total BF (kg) - post ***	**Right Total BF (kg) - pre**	**Right Total BF (kg) - post**	**Left Forearm BF (kg) - pre**	**Left Forearm BF (kg) - post**	**Right Forearm BF (kg) - pre**	**Right Forearm BF (kg) - post**	**Left Upper BF (kg) - pre**	**Left Upper BF (kg) - post**	**Right Upper BF (kg) - pre**	**Right Upper BF (kg) - post**
CHO	0.93 (0.14)	0.84 (0.13)	1.00 (0.14)	0.91 (0.13)	0.24 (0.04)	0.21 (0.03)	0.27 (0.05)	0.25 (0.04)	0.69 (0.10)	0.63 (0.10)	0.72 (0.10)	0.65 (0.09)
MILK	0.79 (0.13)	0.73 (0.11)	0.78 (0.12)	0.77 (0.13)	0.20 (0.03)	0.19 (0.03)	0.21 (0.03)	0.22 (0.04)	0.60 (0.10)	0.55 (0.09)	0.57 (0.10)	0.55 (0.09)

Values are averages with SEM in parentheses

***** indicates significant change for groups combined from pre to post training ($P<0.05$)

** indicates significant change for groups combined from pre to post training ($P<0.01$)

Table 5. Leg body composition measurements before and after 10 wk of resistance training

	Left Total LBM (kg) - pre	**Left Total LBM (kg) - post ****	**Right Total LBM (kg) - pre**	**Right Total LBM (kg) - post ****	**Left Lower LBM (kg) - pre**	**Left Lower LBM (kg) - post**	**Right Lower LBM (kg) - pre**	**Right Lower LBM (kg) - post**	**Left Upper LBM (kg) - pre**	**Left Upper LBM (kg) - post ***	**Right Upper LBM (kg) - pre**	**Right Upper LBM (kg) - post ****
CHO	10.01 (0.49)	10.07 (0.43)	10.10 (0.47)	10.24 (0.43)	3.26 (0.12)	3.24 (0.10)	3.29 (0.11)	3.29 (0.11)	6.75 (0.39)	6.83 (0.34)	6.81 (0.37)	6.95 (0.34)
MILK	10.01 (0.50)	10.38 (0.53)	10.19 (0.56)	10.55 (0.53)	3.23 (0.12)	3.29 (0.13)	3.33 (0.14)	3.38 (0.15)	6.77 (0.40)	7.08 (0.41)	6.86 (0.43)	7.17 (0.39)

	Left Total BF (kg) - pre	**Left Total BF (kg) - post**	**Right Total BF (kg) - pre**	**Right Total BF (kg) - post ***	**Left Lower BF (kg) - pre**	**Left Lower BF (kg) - post**	**Right Lower BF (kg) - pre**	**Right Lower BF (kg) - post**	**Left Upper BF (kg) - pre**	**Left Upper BF (kg) - post**	**Right Upper BF (kg) - pre**	**Right Upper BF (kg) - post ***
CHO	3.18 (0.53)	3.11 (0.49)	3.42 (0.49)	3.10 (0.44)	0.96 (0.16)	0.92 (0.16)	0.98 (0.16)	0.95 (0.15)	2.21 (0.38)	2.19 (0.33)	2.44 (0.33)	2.14 (0.29)
MILK	2.88 (0.54)	2.77 (0.53)	2.94 (0.54)	2.82 (0.52)	0.83 (0.14)	0.78 (0.12)	0.83 (0.12)	0.79 (0.12)	2.04 (0.40)	1.99 (0.41)	2.11 (0.42)	2.04 (0.41)

Values are averages with SEM in parentheses

***** indicates significant change for groups combined from pre to post training ($P<0.05$)

** indicates significant change for groups combined from pre to post training ($P<0.01$)

Table 6. Strength before and after 10 wk of resistance training

	Leg Press-pre (kg)	**Leg Press-post (kg) *****	**Leg Ext-pre (kg)**	**Leg Ext-post (kg) *****	**Leg Curl-pre (kg)**	**Leg Curl-post (kg) *****	**Bench Press-pre (kg)**	**Bench Press-post (kg) *****	**Shoul Press-pre (kg)**	**Shoul Press-post (kg) *****	**Lat Pull-pre (kg)**	**Lat Pull-post (kg) *****	**Arm Curl-pre (kg)**	**Arm Curl-post (kg) *****
CHO	168.4 (22.7)	293.4 (25.6)	101.3 (7.4)	151.0 (9.1)	127.3 (5.9)	157.8 (7.5)	88.4 (6.7)	112.9 (7.5)	85.4 (7.1)	113.1 (6.5)	78.8 (4.6)	91.2 (4.8)	54.2 (4.0)	60.2 (3.8)
MILK	186.3 (15.6)	317.0 (17.3)	113.2 (4.9)	154.1 (6.0)	124.5 (5.6)	161.8 (11.1)	88.0 (4.1)	114.1 (7.3)	82.6 (5.6)	114.3 (7.2)	83.2 (3.8)	94.3 (4.0)	45.1 (2.7)	60.9 (4.3)

Values are averages with SEM in parentheses

******* indicates significant change for groups combined from pre to post training ($P<0.001$)

Table 7. Resting hormone concentrations before and after 10 wk of training

	Total Testosterone - Pre ng/ml)	**Total Testosterone - post (ng/ml) *****	**Free Testosterone-pre (pg/ml)**	**Free Testosterone-post (pg/ml) ***	**Insulin-pre (uIU/ml)**	**Insulin-post (uIU/ml) ****	**IGF-1-pre (ng/l)**	**IGF-1-post (ng/l)**
CHO	6.7 (0.4)	5.5 (0.4)	29.5 (1.8)	25.4 (2.1)	8.9 (1.2)	13.6 (2.1)	448.5 (50.2)	456.4 (44.0)
MILK	6.5 (0.5)	5.5 (0.4)	27.5 (2.5)	25.2 (1.4)	10.7 (1.7)	15.0 (3.2)	354.3 (35.3)	385.0 (42.7)

Values are averages with SEM in parentheses

* indicates significant change for groups combined from pre to post training ($P<0.05$)

** indicates significant change for groups combined from pre to post training ($P=0.01$)

*** indicates significant change for groups combined from pre to post training ($P<0.001$)

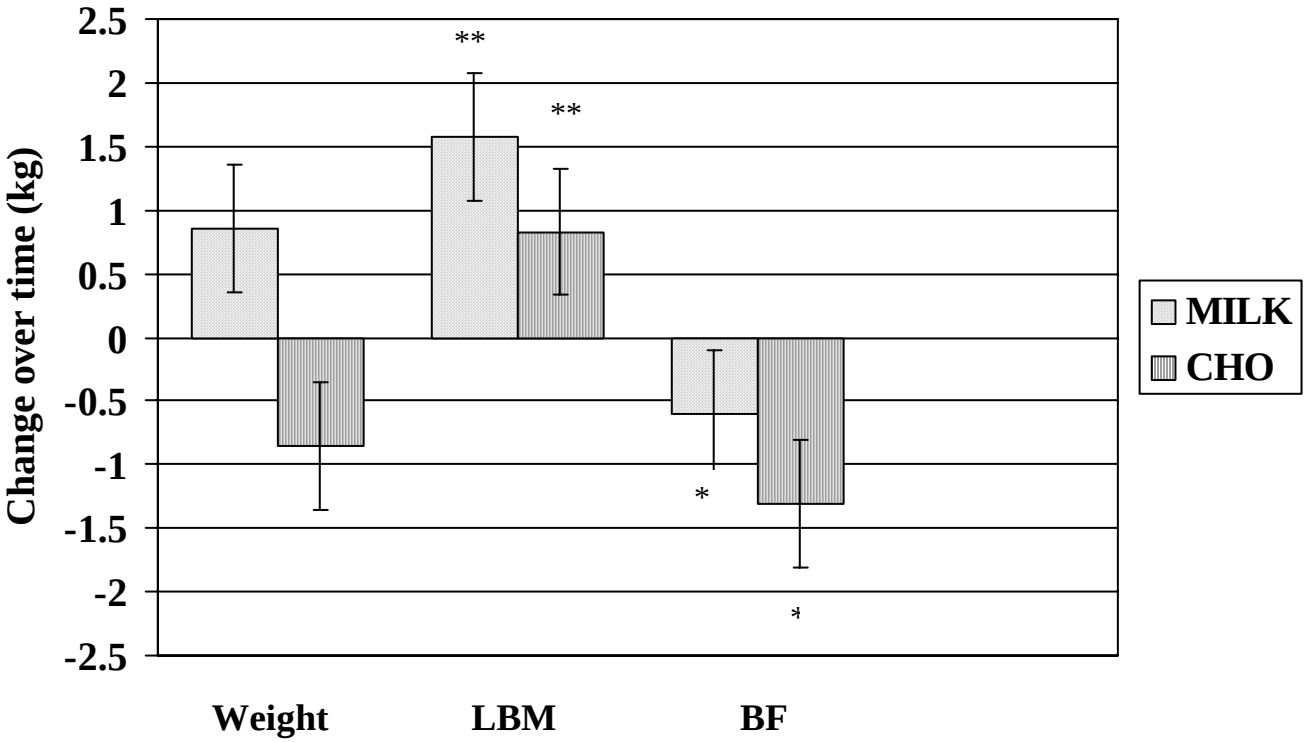
Table 8. Estimated dietary intake before and after 10 wk of resistance training

	Energy-wk 0 (kcals)	**Energy-wk 10 (kcals)**	**CHO-wk 0 (%)**	**CHO-wk 10 (%)**	**FAT-wk 0 (%)**	**FAT-wk 10 (%)**	**PRO-wk 0 (%)**	**PRO-wk 10 (%)**	**PRO-wk 0 (g/kg)**	**PRO-wk 10 (g/kg)**	**Ca^{++}-wk 0 (mg)**	**Ca^{++}-wk 10 (mg)**
CHO	2909.4 (272.9)	2574.5 (202.4)	51.1 (4.5)	50.8 (1.9)	29.3 (2.4)	29.4 (3.1)	12.8 (1.7)	16.4 (2.5)	1.3 (0.26)	1.2 (0.12)	884.7 (98.9)	1024.4 (100.3)
MILK	2488.4 (276.1)	2682.6 (271.7)	48.6 (4.2)	49.3 (3.5)	31.7 (4.0)	33.2 (1.5)	17.7 (1.9)	14.3 (0.75)	1.2 (0.21)	1.3 (0.16)	852.7 (184.8)	971.4 (117.9)

Values are averages with SEM in parentheses

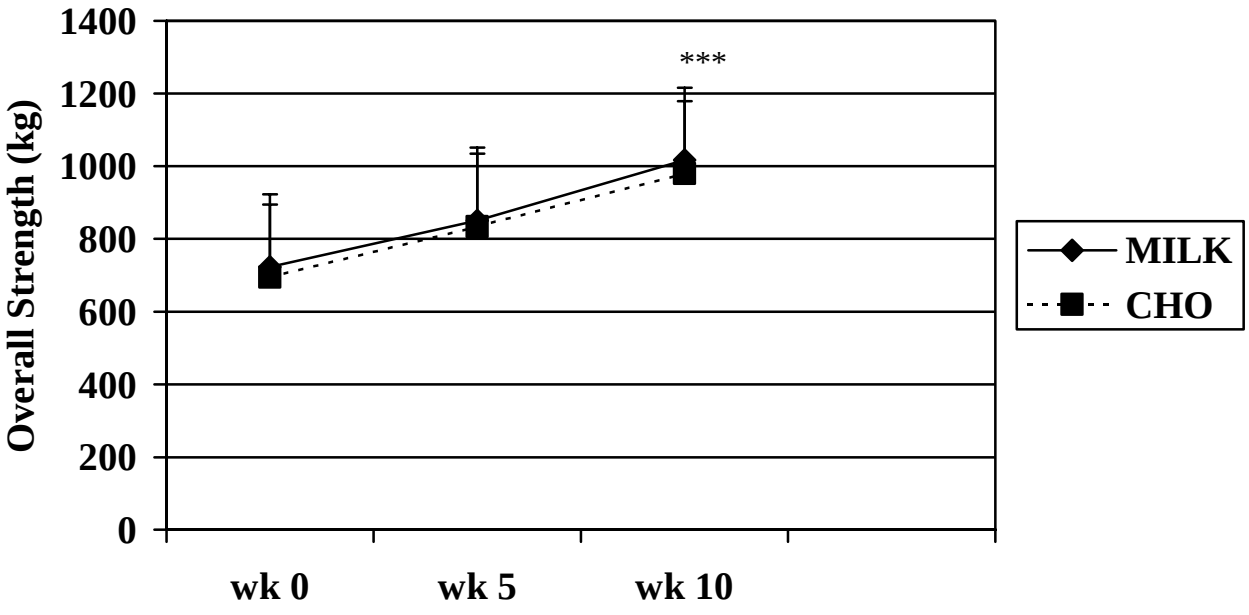
No statistical differences

Figure 1. Changes in body composition after 10 wk of resistance training



* P<0.05 for both groups combined from pre to post training
** P<0.01 for both groups combined from pre to post training

Figure 2. Change in overall strength during the 10 wk training period



*** P<0.001 for both groups combined from pre to post training

CHAPTER 4:

Summary and Recommendations

Research suggests that dietary intake may have a major impact on the amount of change in muscle strength and size as a result of resistance exercise. While some studies show that a daily protein intake of 1.6 to 1.8 g/kg is sufficient for protein balance, it has also been shown that a protein intake of 0.9 g/kg is inadequate and 2.4 g/kg is excessive (56, 78). Nutritional supplementation has grown in popularity among individuals who hope to accelerate the results of weight lifting (44).

Some studies have shown that nutritional supplementation in combination with long term resistance training can lead to further increases in muscle strength and hypertrophy. For example, subjects who consumed 1.5 g/kg protein and participated in a 6 d/wk resistance exercise program saw a 5% increase in muscle density and a 18.4% increase in 1-RM leg squat and 5.9% increase in 1-RM bench press, while a 1.5 g/kg carbohydrate supplement promoted a 6.2% increase in muscle density and a 9.3% increase in 1-RM bench press along with a 2.4% increase in 1-RM leg squat (57). In another study, although there was no additional increase in muscle strength compared to placebo, subjects consuming a mixed macronutrient supplement (EXCEED) significantly increased lean body mass (3.6 kg) following a 10 wk resistance training program (38). Other studies have shown similar results in body composition in elderly subjects consuming a protein supplement in combination with resistance exercise (19, 62). These studies show that a nutritional supplement including one or a mixture of macronutrients may maximize the benefits of resistance training on muscle strength and size.

Several anabolic hormones have been linked to changes in muscle size and strength resulting from resistance training. First, although it has not yet been proven that resting insulin concentrations are changed with resistance training, research has shown

that insulin plays a major role in muscle protein metabolism. Some studies indicate that insulin works through a direct impact on muscle protein synthesis (9), while others show that insulin reduces the rate of muscle protein breakdown (21, 37, 73, 79), and some research proves that insulin impacts both muscle protein synthesis and muscle protein degradation (7). Although the exact mechanism is not yet clear, research has shown that insulin provides an anabolic condition in muscle protein that may, over time, lead to increases in muscle size and strength.

Free and total testosterone are also regarded as anabolic hormones which may be involved with changes in muscle strength and hypertrophy resulting from resistance exercise. There is some controversy regarding the changes in basal concentrations of both free and total testosterone in response to exercise. While some studies report a 7-13% increase in basal total testosterone concentrations after just 7 to 12 wk of resistance exercise (6, 29), others found up to a 2% reduction following 12 wk of training (24), and some research has found no change in resting total testosterone concentrations (42, 47, 53, 64). Similarly, although some studies found no change in resting free testosterone concentrations following a long term resistance training program (17, 29, 42), one study showed a 20% increase in basal free testosterone after 10 wk of training (53) and another showed a 6% decline after 16 wk of training (4). Still, however, the research is conclusive that testosterone works in an anabolic fashion, either through direct effects on muscle protein synthesis, degradation or a combination to promote muscle hypertrophy and increased muscle strength (30, 34, 40).

Finally, insulin-like growth hormone-1 (IGF-1) has also been identified as an anabolic hormone. Many studies have failed to find a significant change in basal IGF-1

concentrations following a long term resistance training program (8, 53, 60, 64, 94), although one study showed a 29-40% increase after 13 wk of training (13). The role of IGF-1 on skeletal muscle hypertrophy may act through control over muscle protein metabolism (36) or through a connection with DNA (2).

Due to the previously described research, the purpose of our study was to compare the effects of a milk beverage and a carbohydrate beverage consumed after workouts following a 10 wk resistance training program on body composition, muscle strength and endocrine function.

Nineteen male subjects volunteered from the Virginia Tech campus to participate in the study. All subjects had not participated in any organized resistance training program or consumed any nutritional supplements not approved by the researchers for 3 mo prior to the start of the study. Subjects were assigned to either a milk supplement (MILK) or a carbohydrate supplement (CHO) based on usual dairy intake as well as body weight. All subjects were involved in a 3 d/wk periodized resistance training program lasting 10 wk.

Anthropometric measurements revealed no significant changes in body weight from pre to post training in either treatment, however MILK increased body weight and CHO reduced body weight by almost 1 kg. Right and left arm circumference measurements significantly increased (2%, 2.3%), while right and left thigh and chest circumference showed a tendency to increase a the end of the 10 wk ($P=0.1$; $P=0.08$; $P=0.07$, respectively).

Body composition was measured pre and post training by DEXA. Although there were no significant differences between treatments, the MILK group tended to increase

lean body mass more than CHO (P=0.10), and the CHO group tended to reduce percent body fat more than MILK (P=0.25). Specifically, MILK increased lean body mass by 1.6 kg and reduced percent body fat by 0.9%, while CHO increased lean body mass by 0.8 kg and decreased percent body fat by 1.4%. All subjects significantly increased left total arm, left upper arm, right upper arm, left total leg, right total leg, left upper leg and right upper leg lean body mass ($P<0.05$) and significantly reduced absolute body fat in the right total leg, right upper leg and left total arm ($P<0.05$), with no significant differences between treatments.

Muscle strength increased from 13.8 to 87.4% in each of the seven exercises by the end of the training period in all subjects, and there was a 44% improvement in overall muscle strength.

Resting total and free testosterone concentrations significantly decreased from pre to post training ($P<0.001$; $P<0.05$, respectively) in all subjects. Although there were no significant changes in basal IGF-1 concentrations, basal insulin concentrations significantly increased at the end of the 10 wk ($P<0.01$), with no differences between groups.

Resistance training and nutritional supplementation with either MILK or CHO had no effect on dietary quality or quantity, and there were no changes or differences between groups in dietary intake over the 10 wk training program.

Although it is difficult to speculate, it appears that the resistance training program alone caused the changes in body composition and muscle strength with no added benefit of nutritional supplementation. It is known that a resistance training program can induce

significant increases in lean tissue and muscle strength, however the exact mechanism is not certain.

In summary, increased lean body mass, reduced body fat and increased muscular strength appeared to be a result of the resistance training protocol with no added benefit from supplementation with either low fat chocolate milk or a carbohydrate-electrolyte beverage. Resistance training also caused a significant decline in resting total and free testosterone concentrations and a significant increase in resting insulin concentrations, however we cannot conclude whether endocrine function was related to the muscular adaptations. Nevertheless, a long term periodized resistance training program is beneficial for individuals looking to improve body composition and increase muscle strength.

Recommendations for Future Research

1. The nutritional supplementation failed to affect dietary quality or quantity in our study. Gater et al. (38) showed that subjects supplemented with a mixed nutrient supplement increased overall energy intake as well as significantly increased body weight and fat free mass compared to subjects consuming a placebo following 10 wk of training. Therefore, increasing the subjects' overall calorie intake through by increasing the protein content of the MILK supplement and increasing the carbohydrate content of the CHO supplement may provide insight as to whether the extra calories or the specific macronutrient makeup helps maximize gains in body composition during a resistance training program.

2. To determine whether dietary supplementation had any added effect on body composition and muscle strength during a resistance training program, it would be beneficial to add a control group. This control group would be involved in the same resistance training protocol, however they would consume a placebo instead of MILK or CHO. A control group would help support or refute the theory that the resistance training alone caused the improved body composition and increased muscular strength in our study.

3. We showed a significant reduction in resting free and total testosterone and a significant increase in resting insulin concentrations following the 10 wk training program. It is difficult to correlate changes in body composition and

muscular strength to changes in resting concentrations of these anabolic hormones. Kraemer et al. (53) observed a temporal effect of resistance training on endocrine function. They showed that resting total testosterone concentrations increased 15% after just 3 wk of resistance training, however concentrations dropped to baseline levels by the 10^{th} wk of training. Therefore, it may be beneficial to measure resting hormone concentrations weekly during the 10 wk training period, instead of just pre- and post training in order to observe temporal changes in endocrine function.

4. Untrained subjects may have a greater ability for strength and fat free mass gains than trained subject due to an enhanced muscular adaptation with the onset of resistance training (54). However, some research shows that advanced weight lifters may have greater neural adaptations that would promote increased strength gains during a resistance training program (52). In future experiments, it would be interesting to observe whether previously trained subjects would produce the same results following the same periodized resistance training protocol as our subjects.

5. It is well known that muscle fibers adapt and change with a heavy resistance training program. Little is known about the time course of muscle plasticity and the individual effects of resistance training on muscle fiber adaptations. Staron et al. (75) observed significant changes in specific muscle fiber types (I, IIa, IIb) after only 2 wk of training, and they correlated these changes with

strength gains accrued during training. Therefore, it would be interesting to determine the effect of nutritional supplementation in combination with resistance training on changes in muscle fiber composition, cross-sectional area and myosin heavy chain content, and the resulting effects on strength gains and body composition changes in previously untrained men.

6. Overtraining was mentioned as a possible reason for the decline in resting concentrations of testosterone over the 10 wk training period. In order to determine whether overtraining is a valid and accurate explanation, cortisol concentrations should be measured. Fry et al. (35) reported that increased resting cortisol concentrations, in response to a long term resistance training program, may indicate overtraining. The ratio between testosterone and cortisol is often used as an indicator of the anabolic/catabolic status during training. Measuring resting cortisol concentrations would provide the catabolic effects of dietary supplementation and resistance training on endocrine control.

7. One added benefit of using DEXA to measure body composition is its ability to determine bone mineral density. Research has shown that exercise has an important effect on maintaining and even increasing bone mineral density in female subjects. Also, dietary intake is another factor that has control over bone mineral density. Overall, our subjects consumed below the RDA in calcium (966.2 mg vs. 1200 mg) during the experimental period. For future

studies, it would be interesting to measure the effects of dietary supplementation and resistance exercise on bone mineral density in young male subjects.

APPENDIX A:

Detailed Description of Research Methods and Procedures

Subject Selection and Screening

Twenty-one males between the ages of 18 and 25 y were selected. Subjects were not involved in an organized resistance training program and were not taking any nutritional supplements other than multi-vitamins for 3 mo prior to the start of the study.

Subjects completed a health history questionnaire that screened for contraindications to intense resistance exercise, muscle biopsy and diet manipulation. For example, some contraindications include diabetes, cardiovascular problems, muscular-skeletal limitations or injuries, milk allergy, lidocaine allergy or lactose intolerance. All subjects signed an informed consent form.

Subject Pre-testing

Subjects performed 1-RM lifts for seven exercises, including: leg press, leg curl, leg extension, bench press, shoulder press, lateral pull down and arm curl using Body Masters equipment. Subjects first lifted ten repetitions at a light weight as a warm-up and familiarization to the equipment. Weight was then increased for each following trial until subjects could only lift the load one time. There was a 1.5 min rest in between each trial. Additional 2.3 kg, 1.4 and 0.5 kg weights were added for more accurate 1-RM measurements.

Subjects were weighed in the fasted state. Upper arm, thigh and chest circumference measurements were taken as the average of duplicate measurements. Total and regional body composition were measured using dual energy x-ray absorptiometry (DEXA) with a Hologic QDR4500A. All metal objects (clothes, jewelry) were removed before testing. After the whole body scan was completed, regions of interest (upper arms, forearms, upper legs, lower legs) were measured by manual DEXA

analysis software. The DEXA was calibrated with tissue phantoms prior to each measurement.

Blood collections were taken also in the fasted state. Resting total and free testosterone, IGF-1 and insulin concentrations were analyzed.

Nutritional Supplementation

Subjects completed a dairy frequency checklist in order to determine usual intake (Appendix G). Subjects were then assigned to either the MILK group or the CHO group so that both groups had a similar baseline dairy intake. The groups were further manipulated so that body weight was also similar.

The MILK supplement consisted of low fat chocolate milk, and contained 0.92 g/kg carbohydrate, 0.21 g/kg protein and 0.06 g/kg fat. The CHO supplement consisted of Gatorade powder, and contained 1.25 g carbohydrate. Each supplement was to provide 5 kcal/kg for each subject.

Figure 3. Sample Subject Calculation for Nutritional Supplementation

Subject X:

Body weight: 80 kg

CHO: 5 kcal * 80 kg = 400 kcal

1.25 g * 80 kg = 100 g carbohydrate

MILK: 5 kcal * 80 kg = 400 kcal

0.92 g * 80 kg = 73.6 g protein

0.21 g * 80 kg = 16.8 g carbohydrate

0.06 g * 80 kg = 4.8 g fat

Exercise Training

Subjects reported to the Hokie gym at a specified time 3 d/wk for 1 h. Seven exercises, including: leg press, leg curl, leg extension, bench press, shoulder press, lateral pull down, arm curl were performed. Three sets of abdominal crunches, including 30 repetitions to the front and 20 repetitions to each side, were also performed at each session. Training intensity for the resistance training program was determined using the subjects' 1-RMs. Another strength assessment was completed at week five and the intensity for the remainder of the study was based on these new 1-RMs.

Supplements were consumed in an average of 3.25 min following each workout.

Figure 4. Sample Subject Calculation for Resistance Training Protocol

Subject X

Leg Press 1-RM (wk 0): 100 kg

Leg Press 1-RM (wk 5): 200 kg

Week	1-RM (kg)	Sets	Repetitions	Intensity (%)	Weight (kg)
1	100	3	12	55	55
2	100	4	10	64	64
3	100	4	10	67	67
4	100	4	8	70	70
5	100	4	6	73	73
6	200	4	6	76	152
7	200	5	5	82	164
8	200	5	5	85	170
9	200	3	3	94	188
10	200	3	3	97	194

APPENDIX B:

Raw Data Tables

Table 1. Individual Subject Body Composition

Subject (CHO)	**Height (cm)**	**BW-pre (kg)**	**BW-post**	**BF-pre (kg)**	**BF-post**	**% BF-pre**	**% BF-post**	**LBM-pre (kg)**	**LBM-post**
1	186.81	89.2	86.0	16.9	15.71	18.8	18.0	69.8	68.62
3	176.73	82.1	81.6	16.9	15.68	20.4	19.0	62.84	63.68
5	184.54	109.9	106.9	30.19	28.53	27.1	26.3	77.18	76.13
12	171.54	82.1	76.5	20.01	13.17	24.1	16.9	60.57	62.16
13	185.01	64.4	65.6	9.00	8.40	13.9	12.7	53.30	55.16
14	160.00	73.1	72.6	15.28	13.79	20.8	18.7	55.66	57.53
15	165.54	59.1	62.9	8.42	9.71	14.1	15.2	48.77	51.75
18	173.08	79.9	81.4	19.24	20.05	23.9	24.4	59.02	59.92
21	174.50	78.1	76.8	15.24	14.37	19.3	18.5	60.83	60.50
Mean	**175.3**	**79.8**	**78.9**	**16.8**	**15.5**	**20.3**	**18.9**	**60.9**	**61.7**
± SEM	**3.0**	**4.9**	**4.3**	**2.2**	**2.0**	**1.5**	**1.4**	**2.9**	**2.4**
Subject (MILK)	**Height (cm)**	**BW-pre (kg)**	**BW-post**	**BF-pre (kg)**	**BF-post**	**% BF-pre**	**% BF-post**	**LBM-pre (kg)**	**LBM-post**
2	180.94	111.3	111.3	31.45	30.22	28	26.8	77.81	79.76
4	168.73	68.4	66.3	12.27	10.44	17.9	15.5	53.59	54.24
6	176.03	61.8	64.3	7.22	8.65	11.6	13.3	52.78	53.95
7	181.43	58.1	60.1	5.43	5.94	9.3	9.8	50.38	51.76
10	183.64	74.2	75.3	14.23	13.05	18.7	17.1	58.69	59.98
11	173.21	97.5	97.7	26.44	27.46	26.9	27.8	68.92	68.20
16	177.27	79.6	74.3	19.01	13.2	23.7	17.6	58.61	58.96
17	188.56	85.4	88.5	11.14	11.06	12.9	12.4	71.75	74.83
19	178.11	73.8	78.2	13.28	14.24	17.9	18.0	58.18	62.00
20	189.09	69.8	72.5	8.31	8.56	11.7	11.6	59.30	62.14
Mean	**179.7**	**78.0**	**78.9**	**14.9**	**14.3**	**17.9**	**17.0**	**61.0**	**62.6**
± SEM	**2.0**	**5.2**	**5.1**	**2.7**	**2.6**	**2.1**	**1.9**	**2.8**	**2.9**

Table 2. Individual Subjects Trunk Body Composition

Subject (CHO)	**LBM-pre (kg)**	**LBM-post**	**BF-Pre (kg)**	**BF-post**
1	35.98	35.53	7.63	7.27
3	27.17	28.11	6.81	5.78
5	37.25	36.97	11.76	10.95
12	28.97	29.55	8.98	5.08
13	26.82	27.95	3.32	3.28
14	28.64	29.70	5.75	5.03
15	23.15	24.75	3.31	4.16
18	28.83	29.46	10.34	10.81
21	29.02	28.72	5.96	5.75
Mean	**28.73**	**29.40**	**7.03**	**6.36**
± SEM	**1.40**	**1.22**	**1.10**	**1.03**
Subject (MILK)	**LBM-pre (kg)**	**LBM-post**	**BF-Pre (kg)**	**BF-Post**
2	39.28	39.44	16.51	15.47
4	26.53	26.53	5.28	4.34
6	26.11	26.42	2.67	3.54
7	24.90	24.83	1.91	2.25
10	28.93	29.50	5.42	4.95
11	31.03	30.47	10.43	11.34
16	29.59	29.59	8.78	5.42
17	35.76	37.32	4.76	4.44
19	28.36	30.63	5.75	6.21
20	29.74	30.40	3.07	3.59
Mean	**28.99**	**29.52**	**5.34**	**5.12**
± SEM	**1.07**	**1.20**	**0.93**	**0.87**

Table 3. Individual Subject Regional Arm Lean Body Mass

Subject (CHO)	Lf Tot LBM - pre (kg)	Lf Tot LBM - post	Rt Tot LBM - pre (kg)	Rt Tot LBM - post	Lf Lwr LBM - pre (kg)	Lf Lwr LBM - Post	Rt Lwr LBM - Pre (kg)	Rt Lwr LBM - post	Lf Upp LBM - Pre (kg)	Lf Upp LBM - post	Rt Upp LBM - Pre (kg)	Rt Upp LBM - post
1	3.9	4.0	4.2	4.4	1.4	1.5	1.5	1.5	2.5	2.5	2.8	2.8
3	4.4	4.5	4.5	4.3	1.7	1.6	1.7	1.6	2.7	2.8	2.8	2.7
5	4.8	4.5	5.2	4.7	1.8	1.9	2.0	1.8	3.0	2.6	3.1	2.9
12	3.6	3.5	3.7	3.8	1.5	1.3	1.5	1.5	2.1	2.2	2.2	2.3
13	3.1	3.3	3.4	3.5	1.3	1.4	1.4	1.5	1.8	1.9	1.9	2.0
14	3.2	3.5	3.2	3.4	1.3	1.4	1.3	1.4	1.9	2.1	2.0	2.0
15	2.7	2.9	2.8	3.3	1.2	1.2	1.1	1.3	1.6	1.8	1.7	2.0
18	3.4	3.4	3.6	3.5	1.4	1.4	1.5	1.5	2.0	2.0	2.2	2.1
21	3.5	3.7	3.8	3.8	1.6	1.5	1.5	1.5	2.0	2.1	2.3	2.4
Mean	**3.6**	**3.7**	**3.8**	**3.9**	**1.4**	**1.5**	**1.5**	**1.5**	**2.2**	**2.2**	**2.3**	**2.4**
± SEM	**0.22**	**0.18**	**0.24**	**0.16**	**0.07**	**0.07**	**0.08**	**0.05**	**0.16**	**0.12**	**0.16**	**0.12**
Subject (MILK)	**Lf Tot LBM - pre (kg)**	**Lf Tot LBM - post**	**Rt Tot LBM - pre (kg)**	**Rt Tot LBM - post**	**Lf Lwr LBM - pre (kg)**	**Lf Lwr LBM - Post**	**Rt Lwr LBM - Pre (kg)**	**Rt Lwr LBM - Post**	**Lf Upp LBM - Pre (kg)**	**Lf Upp LBM - post**	**Rt Upp LBM - Pre (kg)**	**Rt Upp LBM - post**
2	4.6	5.0	4.4	4.7	1.6	1.8	1.6	1.7	3.0	3.2	2.7	3.1
4	3.2	3.2	3.4	3.5	1.2	1.2	1.3	1.3	2.0	2.0	2.1	2.2
6	3.2	3.4	3.4	3.5	1.4	1.4	1.5	1.6	1.8	2.0	1.9	2.0
7	2.8	3.0	2.9	3.2	1.2	1.3	1.3	1.4	1.6	1.7	1.7	1.8
10	2.7	2.9	3.2	3.3	1.2	1.2	1.3	1.3	1.6	1.7	1.9	1.9
11	4.2	4.1	4.4	4.1	1.8	1.7	1.8	1.6	2.5	2.4	2.6	2.5
16	3.4	3.6	3.7	3.7	1.4	1.4	1.5	1.5	2.0	2.2	2.2	2.2
17	4.4	4.9	4.5	4.9	1.8	1.9	1.9	2.0	2.6	3.0	2.6	2.9
19	3.1	3.4	3.4	3.7	1.4	1.4	1.5	1.5	1.7	2.0	1.9	2.2
20	3.5	3.9	3.7	4.0	1.4	1.6	1.6	1.6	2.0	2.3	2.1	2.4
Mean	**3.5**	**3.7**	**3.7**	**3.9**	**1.4**	**1.5**	**1.5**	**1.6**	**2.1**	**2.2**	**2.2**	**2.3**
± SEM	**0.21**	**0.23**	**0.17**	**0.18**	**0.07**	**0.08**	**0.07**	**0.06**	**0.15**	**0.16**	**0.11**	**0.13**

Table 4. Individual Subject Regional Arm Body Fat

Subject (CHO)	Lf Tot BF-pre (kg)	Lf Tot BF-post	Rt Tot BF-pre (kg)	Rt Tot BF-post	Lf Lwr BF-Pre (kg)	Lf Lwr BF-Post	Rt Lwr BF-Pre (kg)	Rt Lwr BF-post	Lf Upp BF-Pre (kg)	Lf Upp BF-post	Rt Upp BF-Pre (kg)	Rt Upp BF-post
1	0.93	0.83	1.1	0.90	0.24	0.22	0.32	0.25	0.69	0.61	0.76	0.65
3	0.97	0.93	0.97	0.97	0.27	0.28	0.24	0.32	0.70	0.65	0.73	0.65
5	1.8	1.7	1.9	1.8	0.57	0.38	0.61	0.50	1.2	1.3	1.3	1.3
12	1.2	0.77	1.2	0.87	0.23	0.16	0.26	0.21	0.95	0.61	0.96	0.66
13	0.41	0.36	0.48	0.40	0.15	0.10	0.16	0.11	0.26	0.26	0.32	0.29
14	0.74	0.71	0.73	0.73	0.19	0.15	0.27	0.19	0.55	0.56	0.46	0.54
15	0.43	0.47	0.57	0.56	0.10	0.10	0.13	0.14	0.33	0.37	0.44	0.42
18	1.1	0.99	1.1	1.0	0.20	0.24	0.19	0.23	0.86	0.75	0.88	0.79
21	0.84	0.75	0.88	0.93	0.25	0.23	0.29	0.33	0.59	0.52	0.59	0.60
Mean	**0.93**	**0.84**	**1.0**	**0.91**	**0.24**	**0.21**	**0.27**	**0.25**	**0.69**	**0.63**	**0.72**	**0.65**
± SEM	**0.14**	**0.13**	**0.14**	**0.13**	**0.04**	**0.03**	**0.05**	**0.04**	**0.10**	**0.10**	**0.10**	**0.09**
Subject (MILK)	**Lf Tot BF-pre (kg)**	**Lf Tot BF-post**	**Rt Tot BF-pre (kg)**	**Rt Tot BF-post**	**Lf Lwr BF-Pre (kg)**	**Lf Lwr BF-post**	**Rt Lwr BF-Pre (kg)**	**Rt Lwr BF-post**	**Lf Upp BF-Pre (kg)**	**Lf Upp BF-post**	**Rt Upp BF-Pre (kg)**	**Rt Upp BF-post**
2	1.5	1.4	1.4	1.5	0.40	0.36	0.36	0.44	1.1	1.1	1.0	1.0
4	0.75	0.65	0.73	0.62	0.19	0.14	0.23	0.16	0.56	0.51	0.50	0.46
6	0.44	0.46	0.43	0.53	0.14	0.16	0.18	0.15	0.30	0.30	0.25	0.38
7	0.31	0.37	0.42	0.39	0.11	0.11	0.12	0.11	0.20	0.26	0.30	0.28
10	0.77	0.63	0.68	0.62	0.17	0.15	0.16	0.16	0.60	0.48	0.52	0.46
11	1.3	1.3	1.4	1.5	0.25	0.30	0.34	0.50	1.0	0.95	1.1	1.0
16	1.1	0.79	1.1	0.76	0.24	0.20	0.28	0.18	0.90	0.59	0.86	0.58
17	0.52	0.52	0.50	0.58	0.17	0.16	0.15	0.20	0.35	0.36	0.35	0.38
19	0.79	0.77	0.69	0.72	0.15	0.18	0.12	0.16	0.64	0.65	0.57	0.56
20	0.42	0.42	0.46	0.47	0.14	0.11	0.14	0.16	0.28	0.31	0.32	0.31
Mean	**0.79**	**0.73**	**0.78**	**0.77**	**0.20**	**0.19**	**0.21**	**0.22**	**0.6**	**0.55**	**0.57**	**0.55**
± SEM	**0.13**	**0.11**	**0.12**	**0.13**	**0.03**	**0.03**	**0.03**	**0.04**	**0.10**	**0.09**	**0.10**	**0.09**

Table 5. Individual Subject Regional Leg Lean Body Mass

Subject (CHO)	Lf Tot LBM - pre (kg)	Lf Tot LBM - post	Rt Tot LBM - pre (kg)	Rt Tot LBM - post	Lf Lwr LBM - pre (kg)	Lf Lwr LBM - post	Rt Lwr LBM - pre (kg)	Rt Lwr LBM - post	Lf Upp LBM - pre (kg)	Lf Upp LBM - post	Rt Upp LBM - pre (kg)	Rt Upp LBM - post
1	10.9	10.3	11.1	10.8	3.1	3.0	3.2	3.0	7.8	7.3	8.0	7.9
3	10.7	10.5	10.7	10.9	3.4	3.3	3.4	3.4	7.4	7.2	7.3	7.5
5	12.8	12.6	12.8	12.7	3.9	3.8	4.0	3.9	8.9	8.8	8.8	8.8
12	10.3	10.8	10.5	11.0	3.5	3.5	3.6	3.7	6.8	7.3	6.9	7.2
13	8.3	8.6	8.5	8.6	2.9	3.0	3.0	3.1	5.4	5.6	5.4	5.5
14	9.2	9.5	9.3	9.5	3.1	3.1	3.2	3.2	6.1	6.4	6.1	6.4
15	8.0	8.4	8.3	8.7	2.7	2.9	2.9	2.9	5.2	5.5	5.4	5.8
18	9.7	9.6	9.7	9.9	3.2	3.2	3.1	3.1	6.6	6.4	6.5	6.8
21	10.2	10.3	10.2	10.1	3.4	3.4	3.3	3.4	6.7	6.9	6.8	6.7
Mean	**10.0**	**10.1**	**10.0**	**10.2**	**3.3**	**3.2**	**3.3**	**3.3**	**6.8**	**6.8**	**6.8**	**7.0**
± SEM	**0.49**	**0.43**	**0.47**	**0.43**	**0.12**	**0.1**	**0.11**	**0.11**	**0.39**	**0.34**	**0.37**	**0.34**
Subject (MILK)	**Lf Tot LBM - pre (kg)**	**Lf Tot LBM - post**	**Rt Tot LBM - pre (kg)**	**Rt Tot LBM - post**	**Lf Lwr LBM - pre (kg)**	**Lf Lwr LBM - post**	**Rt Lwr LBM - pre (kg)**	**Rt Lwr LBM - post**	**Lf Upp LBM - pre (kg)**	**Lf Upp LBM - post**	**Rt Upp LBM - pre (kg)**	**Rt Upp LBM - post**
2	12.7	13.4	13.1	13.5	4.0	3.9	4.2	4.3	8.8	9.5	8.9	9.2
4	8.4	8.7	8.5	8.8	2.6	2.5	2.7	2.6	5.9	6.2	5.8	6.2
6	8.6	8.6	8.4	8.8	3.1	3.1	3.1	3.1	5.4	5.6	5.3	5.7
7	8.4	8.9	8.4	9.1	2.9	3.1	2.9	3.1	5.5	5.8	5.5	6.0
10	9.9	10.3	10.3	10.3	3.2	3.1	3.2	3.3	6.7	7.2	7.1	7.0
11	12.3	12.6	12.9	12.9	3.5	3.8	3.8	3.8	8.9	8.8	9.1	9.1
16	9.2	9.3	9.5	9.5	3.0	3.3	3.2	3.3	6.2	6.1	6.3	6.2
17	11.4	11.8	11.5	11.6	3.5	3.8	3.6	3.8	7.8	8.1	7.8	7.9
19	9.7	10.2	10.1	10.9	3.3	3.1	3.3	3.3	6.5	7.1	6.8	7.6
20	9.4	9.9	9.3	10.1	3.3	3.3	3.2	3.3	6.1	6.7	6.1	6.9
Mean	**10.0**	**10.4**	**10.2**	**10.6**	**3.2**	**3.3**	**3.3**	**3.4**	**6.8**	**7.1**	**6.9**	**7.2**
± SEM	**0.50**	**0.53**	**0.56**	**0.53**	**0.12**	**0.13**	**0.14**	**0.15**	**0.4**	**0.41**	**0.43**	**0.39**

Table 6. Individual Subject Regional Leg Body Fat

Subject (CHO)	Lf Tot BF-pre (kg)	Lf Tot BF-post	Rt Tot BF-pre (kg)	Rt Tot BF-post	Lf Lwr BF-Pre (kg)	Lf Lwr BF-Post	Rt Lwr BF-Pre (kg)	Rt Lwr BF-post	Lf Upp BF-Pre (kg)	Lf Upp BF-post	Rt Upp BF-Pre (kg)	Rt Upp BF-post
1	2.9	2.8	3.4	2.9	1.1	0.95	0.99	1.1	1.8	1.8	2.4	1.8
3	4.0	3.9	4.2	3.7	1.1	1.2	1.2	1.2	2.9	2.7	2.9	2.6
5	6.8	6.6	6.6	6.2	2.1	2.1	2.1	2.0	4.7	4.5	4.6	4.2
12	3.8	2.7	3.8	2.7	1.0	0.87	1.0	0.81	2.8	1.9	2.8	1.9
13	1.9	1.7	2.0	1.7	0.55	0.50	0.60	0.53	1.3	1.2	1.4	1.2
14	2.9	2.7	3.0	2.9	0.76	0.70	0.87	0.75	2.2	2.0	2.2	2.1
15	1.5	1.7	1.6	1.8	0.44	0.39	0.39	0.49	1.1	1.3	1.2	1.3
18	2.8	3.1	2.8	3.0	0.67	0.69	0.69	0.83	2.2	2.4	2.1	2.2
21	2.0	2.9	3.3	2.9	0.96	0.92	0.99	0.91	1.1	2.0	2.3	2.0
Mean	**3.2**	**3.1**	**3.4**	**3.1**	**0.96**	**0.92**	**0.98**	**0.95**	**2.2**	**2.2**	**2.4**	**2.1**
± SEM	**0.53**	**0.49**	**0.49**	**0.44**	**0.16**	**0.16**	**0.16**	**0.15**	**0.38**	**0.33**	**0.33**	**0.29**
Subject (MILK)	**Lf Tot BF-pre (kg)**	**Lf Tot BF-post**	**Rt Tot BF-pre (kg)**	**Rt Tot BF-post**	**Lf Lwr BF-Pre (kg)**	**Lf Lwr BF-Post**	**Rt Lwr BF-Pre (kg)**	**Rt Lwr BF-post**	**Lf Upp BF-Pre (kg)**	**Lf Upp BF-post**	**Rt Upp BF-Pre (kg)**	**Rt Upp BF-post**
2	5.4	5.5	5.6	5.2	1.5	1.5	1.5	1.3	3.9	4.0	4.1	4.0
4	2.2	1.9	2.3	2.0	0.70	0.69	0.69	0.73	1.5	1.2	1.6	1.2
6	1.4	1.6	1.4	1.6	0.38	0.39	0.38	0.38	1.0	1.2	0.99	1.3
7	0.91	1.1	1.0	1.1	0.37	0.40	0.45	0.41	0.54	0.65	0.59	0.65
10	3.1	3.0	3.3	2.8	0.76	0.90	0.82	0.85	2.3	2.1	2.4	2.0
11	6.1	5.9	6.1	6.2	1.7	1.4	1.5	1.5	4.4	4.6	4.6	4.7
16	3.4	2.6	3.6	2.7	0.97	0.75	1.1	0.77	2.4	1.8	2.6	2.0
17	2.1	2.1	2.0	2.2	0.76	0.57	0.71	0.61	1.4	1.6	1.3	1.5
19	2.6	2.7	2.5	2.8	0.69	0.79	0.73	0.79	1.9	1.9	1.8	2.0
20	1.6	1.4	1.7	1.6	0.49	0.43	0.57	0.53	1.1	0.97	1.1	1.1
Mean	**2.9**	**2.8**	**2.9**	**2.8**	**0.83**	**0.78**	**0.83**	**0.79**	**2.0**	**2.0**	**2.1**	**2.0**
± SEM	**0.54**	**0.53**	**0.54**	**0.52**	**0.14**	**0.12**	**0.12**	**0.12**	**0.40**	**0.41**	**0.42**	**0.41**

Table 7. Individual Subject Resting Hormone Concentrations

Subject (CHO)	**TT- pre (ng/ml)**	**TT- post**	**FT- pre (pg/ml)**	**FT- post**	**IGF-1- pre (ng/l)**	**IGF-1- post**	**Insulin- pre (uIU/ml)**	**Insulin- post**
1	5.8	5.2	29.5	23.6	438.8	612.4	13.0	20.7
3	5.7	4.8	25.5	17.0	330.7	528.5	5.0	23.0
5	5.2	4.3	22.6	24.5	403.9	389.9	7.6	14.6
12	7.2	7.0	28.0	25.4	337.8	339.5	9.1	6.8
13	6.2	5.7	27.3	25.9	558.1	522.8	11.9	16.9
14	8.0	5.3	37.0	22.0	387.5	298.7	7.4	9.4
15	8.7	6.9	37.5	35.0	681.3	616.2	5.6	8.4
18	5.9	3.2	24.7	19.6	653.5	523.8	14.7	17.2
21	8.0	7.0	33.0	36.0	245.3	275.6	5.5	5.2
Mean	**6.7**	**5.5**	**29.5**	**25.4**	**448.5**	**456.4**	**8.9**	**13.6**
± SEM	**0.42**	**0.44**	**1.8**	**2.1**	**50.2**	**44.0**	**1.2**	**2.1**
Subject (MILK)	**TT- pre (ng/ml)**	**TT- post**	**FT- pre (pg/ml)**	**FT- post**	**IGF-1- pre (ng/l)**	**IGF-1- post**	**Insulin- pre (uIU/ml)**	**Insulin- post**
2	7.1	5.6	28.9	24.6	364.2	499.5	12.4	32.5
4	8.9	7.1	41.2	24.8	264.2	312.6	6.8	11.2
6	5.5	6.1	19.5	25.6	225.1	281.7	5.9	5.2
7	6.8	6.7	20.2	25.6	342.0	514.5	7.4	6.4
10	4.6	3.7	16.8	19.3	397.5	458.3	7.0	12.8
11	7.2	7.3	36.1	35.1	349.2	262.7	14.1	24.7
16	5.1	3.8	25.9	27.0	306.3	292.8	22.2	23.6
17	6.5	4.7	30.1	19.3	458.3	340.9	11.3	10.4
19	4.3	4.8	23.6	24.8	239.4	242.4	-	-
20	8.9	5.5	33.0	26.0	597.2	644.8	9.3	8.4
Mean	**6.5**	**5.5**	**27.5**	**25.2**	**354.3**	**385.0**	**10.7**	**15.3**
± SEM	**0.52**	**0.41**	**2.5**	**1.4**	**35.3**	**42.7**	**1.7**	**3.1**

Table 8. Individual Subject Dietary Protein Intake

Subject (CHO)	**G/kg pre**	**G/kg post**	**Total g wk 0**	**Total g wk 3**	**Total g wk 6**	**Total g wk 10**	**% wk 0**	**% wk 3**	**% wk 6**	**% wk 10**
1	1.5	1.6	130.9	103.6	88.4	133.6	13	14	11	19
3	1.2	0.97	70.7	85.9	113.6	106.8	11	14	15	13
5	1.1	0.79	122.2	148.7	90.7	84.1	12	14	15	11
12	0.52	1.7	43.1	53.8	125.3	128.5	6	15	21	33
13	1.2	1.5	79.1	73.5	70.8	95.5	14	9	11	14
15	3.0	1.3	175.0	85.2	102.3	81.9	23	16	15	13
18	0.74	0.82	59.3	83.2	62.2	67.0	11	12	14	14
21	1.0	1.4	80.6	83.8	68.5	103.6	12	13	8	14
Mean	**1.3**	**1.2**	**95.1**	**89.7**	**90.2**	**100.1**	**12.8**	**13.4**	**13.8**	**16.4**
± SEM	**0.26**	**0.12**	**15.5**	**9.8**	**8.0**	**8.1**	**1.7**	**0.75**	**1.4**	**2.5**
Subject (MILK)	**G/kg pre**	**G/kg post**	**Total g wk 0**	**Total g wk 3**	**Total g wk 6**	**Total g wk 10**	**% wk 0**	**% wk 3**	**% wk 6**	**% wk 10**
2	1.0	1.2	115.1	151.9	99.3	131.4	26	15	9	13
4	1.2	1.3	82.8	81.2	84.5	86.3	14	12	15	14
7	1.1	1.7	64.2	88.6	81.9	100.4	28	14	12	14
10	2.9	1.7	215.6	142.8	154.2	129.1	20	19	24	14
11	0.92	0.53	90.1	81.8	52.1	51.4	13	15	11	12
16	0.92	2.0	73.1	187.5	80.4	147.2	15	31	16	19
17	1.2	0.77	98.7	78.5	59.1	67.9	14	13	8	13
19	1.1	1.3	83.1	92.8	98.2	104.9	17	14	15	17
20	0.82	0.83	57.4	89.4	96.5	60.0	12	11	13	13
Mean	**1.2**	**1.3**	**97.8**	**110.5**	**89.6**	**97.6**	**17.7**	**16.0**	**13.7**	**14.3**
± SEM	**0.21**	**0.16**	**15.8**	**13.3**	**9.8**	**11.3**	**1.9**	**2.0**	**1.6**	**0.75**

Table 9. Individual Subject Dietary Carbohydrate Intake

Subject (CHO)	**Total g wk 0**	**Total g wk 3**	**Total g wk 6**	**Total g wk 10**	**% wk 0**	**% wk 3**	**% wk 6**	**% wk 10**
1	588.8	316.8	511.2	317.7	57	44	64	45
3	343.4	333.9	338.4	398.9	55	53	45	49
5	379.4	449.9	300.1	419.9	37	45	50	55
12	543.9	225.7	290.3	219.9	75	65	48	57
13	260.1	468.0	368.0	396.2	46	59	58	57
15	300.8	246.3	255.6	303.8	40	48	38	47
18	215.0	283.4	157.8	208.4	40	40	35	43
21	390.0	297.5	446.6	388.1	59	48	53	53
Mean	**377.7**	**327.7**	**333.5**	**331.6**	**51.1**	**50.3**	**48.9**	**50.8**
± SEM	**46.2**	**31.3**	**39.1**	**29.4**	**4.5**	**2.9**	**3.4**	**1.9**
Subject (MILK)	**Total g wk 0**	**Total g wk 3**	**Total g wk 6**	**Total g wk 10**	**% wk 0**	**% wk 3**	**% wk 6**	**% wk 10**
2	207.5	355.6	411.7	427.7	46	36	38	41
4	336.1	311.0	256.5	272.8	55	48	46	45
7	398.8	339.2	403.8	387.7	62	52	60	56
10	482.9	334.4	263.1	537.2	44	45	41	57
11	336.3	284.0	303.4	261.9	49	52	64	59
16	127.9	108.4	189.7	221.7	27	18	37	29
17	416.1	417.5	414.9	283.5	57	69	57	55
19	159.7	270.4	277.6	271.6	33	41	44	43
20	303.5	517.5	470.2	280.4	64	62	61	59
Mean	**307.6**	**326.4**	**332.3**	**327.2**	**48.6**	**47.0**	**49.8**	**49.3**
± SEM	**40.3**	**37.0**	**31.6**	**34.0**	**4.2**	**5.0**	**3.6**	**3.5**

Table 10. Individual Subject Dietary Fat Intake

Subject (CHO)	**Total g wk 0**	**Total g wk 3**	**Total g wk 6**	**Total g wk 10**	**% wk 0**	**% wk 3**	**% wk 6**	**% wk 10**
1	134.9	108.2	86.2	87.5	29	34	24	28
3	91.7	91.5	119.9	125.2	33	33	36	35
5	117.1	175.5	87.8	113.3	26	40	33	34
12	51.9	31.1	47.7	16.8	16	20	18	10
13	101.5	94.9	88.9	92.6	40	27	31	30
15	100.2	75.6	122.5	111.7	30	33	41	39
18	73.0	77.2	63.3	61.7	31	24	31	28
21	85.4	107.6	144.0	99.7	29	39	39	31
Mean	**94.5**	**95.2**	**95.0**	**88.6**	**29.3**	**31.3**	**31.6**	**29.4**
± SEM	**9.1**	**14.4**	**11.3**	**12.3**	**2.4**	**2.5**	**2.7**	**3.1**
Subject (MILK)	**Total g wk 0**	**Total g wk 3**	**Total g wk 6**	**Total g wk 10**	**% wk 0**	**% wk 3**	**% wk 6**	**% wk 10**
2	56.4	156.1	248.7	178.0	28	36	52	38
4	64.8	116.3	60.5	100.5	24	40	25	37
7	81.2	100.2	82.1	91.3	10	35	28	30
10	180.8	116.9	98.8	119.7	37	36	35	29
11	118.5	79.8	53.9	58.2	38	33	25	29
16	94.3	130.1	87.5	124.1	45	49	39	36
17	95.9	47.4	110.5	71.3	30	18	34	31
19	104.5	131.5	115.0	111.2	49	45	41	40
20	51.9	100.0	88.6	61.4	24	27	26	29
Mean	**94.3**	**108.7**	**105.1**	**101.7**	**31.7**	**35.4**	**33.9**	**33.2**
± SEM	**13.2**	**10.6**	**19.2**	**12.5**	**4.0**	**3.1**	**3.0**	**1.5**

Table 11. Individual Subject Estimated Dietary Intake

Subject (CHO)	**Kcals wk 0**	**Kcals wk 3**	**Kcals wk 6**	**Kcals wk 10**	**Mg Ca++ wk 0**	**Mg Ca++ wk 3**	**Mg Ca++ wk 6**	**Mg Ca++ wk 10**
1	4109	2785	3155	2781	1386.4	1600.0	829.8	1608.6
3	2478	2495	2973	3211	946.0	371.0	796.0	1177.3
5	3988	3949	2394	3006	973.3	1436.9	895.8	852.5
12	2821	1389	2279	1523	553.7	585.3	892.3	627.4
13	2218	3069	2505	2784	1015.4	854.2	1076.7	962.6
15	3015	2002	2612	2474	978.6	1648.3	860.5	1027.0
18	2010	2658	1702	1937	626.2	1431.6	1185.4	942.9
21	2636	2471	3395	2880	598.0	859.0	486.1	996.8
Mean	**2909.4**	**2602.3**	**2626.9**	**2574.5**	**884.7**	**1098.3**	**877.8**	**1024.4**
± SEM	**272.9**	**264.9**	**190.6**	**202.4**	**98.9**	**173.7**	**72.9**	**100.3**
Subject (MILK)	**Kcals wk 0**	**Kcals wk 3**	**Kcals wk 6**	**Kcals wk 10**	**Mg Ca++ wk 0**	**Mg Ca++ wk 3**	**Mg Ca++ wk 6**	**Mg Ca++ wk 10**
2	1793	3791	4115	4135	500.9	1716.8	1071.2	1265.3
4	2366	2592	2116	2389	396.5	769.6	790.6	800.5
7	2555	2580	2633	2751	642.6	1086.5	716.9	1034.2
10	4403	2910	2542	3704	2069.2	2273.8	1741.5	1693.5
11	2763	2160	1873	1750	743.9	860.3	488.4	525.4
16	1857	2406	2015	3003	352.2	610.5	398.7	962.4
17	2867	2344	2754	2010	1387.7	1087.0	1003.5	692.5
19	1909	2598	2510	2501	941.8	755.9	1178.2	1069.3
20	1883	3173	2978	1900	639.1	843.6	786.8	699.7
Mean	**2488.4**	**2728.2**	**2615.1**	**2682.6**	**852.7**	**1111.6**	**908.4**	**971.4**
± SEM	**276.1**	**166.3**	**222.9**	**271.7**	**184.8**	**180.6**	**134.6**	**117.9**

Table 12. Individual Subject Muscle Circumference Measurements

Subject (CHO)	Rt Arm-pre (cm)	Rt Arm-post	Lf Arm-pre (cm)	Lf Arm-post	Rt Leg-pre (cm)	Rt Leg-post	Lf leg-pre (cm)	Lf leg-post	Chest-pre (cm)	Chest-post
1	35.6	35.8	34.4	34.0	59.9	59.1	58.8	58.3	101.2	103.3
3	29.4	31.4	29.3	31.0	52.7	52.9	53.2	53.6	89.7	92.0
5	40.6	39.9	39.9	39.1	64.9	64.8	65.8	64.5	113.8	109.5
12	34.6	33.3	34.5	33.3	59.5	56.8	58.7	56.9	101.9	97.5
13	26.5	27.8	24.5	26.5	47.2	49.0	48.5	48.2	82.5	84.4
14	36.4	36.5	36.2	36.0	59.0	59.2	59.3	60.0	98.4	102.4
15	26.3	29.2	26.0	28.7	48.3	50.3	48.7	50.4	86.6	89.9
18	32.2	33.5	32.3	32.0	56.7	59.1	56.1	59.5	99.0	99.4
21	32.6	33.3	32.2	33.0	59.2	58.1	58.1	58.5	94.2	95.9
Mean	**32.7**	**33.4**	**32.1**	**32.6**	**56.4**	**56.6**	**56.4**	**56.7**	**96.4**	**97.1**
± SEM	**1.6**	**1.2**	**1.6**	**1.3**	**2.0**	**1.7**	**1.8**	**1.7**	**3.1**	**2.6**
Subject (MILK)	**Rt Arm-pre (cm)**	**Rt Arm-post**	**Lf Arm-pre (cm)**	**Lf Arm-post**	**Rt Leg-pre (cm)**	**Rt Leg-post**	**Lf leg-pre (cm)**	**Lf leg-post**	**Chest-pre (cm)**	**Chest-post**
2	37.3	37.9	37.0	37.9	62.5	66.4	62.6	66.7	105.5	115.7
4	30.1	31.2	29.7	31.2	51.5	53.1	51.9	52.2	95.7	95.4
6	28.8	29.0	28.0	29.0	48.8	47.8	48.2	47.5	91.0	91.7
7	25.7	26.0	24.2	25.9	46.0	47.9	46.3	47.7	83.5	86.0
10	29.4	29.4	27.5	27.8	55.0	55.8	54.8	55.7	95.7	96.3
11	37.0	37.5	36.4	37.7	68.1	69.4	67.0	69.7	99.9	103.1
16	34.4	32.4	33.6	32.1	55.5	54.0	55.2	53.5	97.5	93.7
17	31.4	32.9	31.5	33.8	56.0	58.1	57.3	58.0	97.2	99.3
19	30.4	32.5	30.0	31.0	54.9	56.6	54.4	57.0	91.0	95.8
20	29.3	30.5	29.2	29.9	52.4	52.4	51.6	52.5	86.8	88.6
Mean	**31.4**	**30.9**	**30.7**	**31.6**	**55.1**	**56.2**	**55.0**	**56.1**	**94.4**	**96.6**
± SEM	**1.2**	**1.1**	**1.3**	**1.2**	**2.0**	**2.2**	**2.0**	**2.3**	**2.0**	**2.6**

Table 13. Individual Subject Percent Strength Change

Subject (CHO)	Leg Pr 5 wks (%)	Leg Pr 10 wks	Leg Curl 5 wks (%)	Leg Curl 10 wks	Leg Ext 5 wks (%)	Leg Ext 10 wks	Ben Pr 5 wks (%)	Ben Pr 10 wks	Shoul Pr 5 wks (%)	Shoul Pr 10 wks	Lat Pull 5 wks (%)	Lat Pull 10 wks	Arm Curl 5 wks (%)	Arm Curl 10 wks	Ov-all 5 wks (%)	Ov-all 10 wks
1	17	43	7	17	13	24	12	21	18	26	15	23	35	50	15	30
3	33	63	11	15	45	53	16	38	19	59	16	16	24	38	24	40
5	11	26	19	38	18	16	4	20	24	38	5	10	8	19	13	31
12	41	69	12	26	27	64	5	35	9	34	0	6	30	50	19	43
13	50	100	13	25	32	68	10	23	2	27	3	27	25	44	20	46
14	46	73	17	26	53	89	27	31	11	13	5	14	17	21	24	39
15	52	119	25	25	20	35	23	40	17	40	0	6	32	50	26	50
18	88	229	25	35	16	41	17	37	17	57	23	38	13	31	34	81
21	47	65	3	12	2	31	5	14	10	22	6	9	10	20	15	29
Mean	**41.7**	**87.4**	**14.7**	**24.3**	**25.1**	**46.8**	**13.2**	**28.8**	**14.1**	**35.1**	**8.1**	**16.6**	**21.6**	**35.9**	**21.1**	**43.2**
± SEM	**7.4**	**19.9**	**2.5**	**2.9**	**5.4**	**7.9**	**2.7**	**3.1**	**2.2**	**5.1**	**2.7**	**3.6**	**3.3**	**4.5**	**2.2**	**5.3**
Subject (MILK)	**Leg Pr 5 wks (%)**	**Leg Pr 10 wks**	**Leg Curl 5 wks (%)**	**Leg Curl 10 wks**	**Leg Ext 5 wks (%)**	**Leg Ext 10 wks**	**Ben Pr 5 wks (%)**	**Ben Pr 10 wks**	**Shoul Pr 5 wks (%)**	**Shoul Pr 10 wks**	**Lat Pull 5 wks (%)**	**Lat Pull 10 wks**	**Arm Curl 5 wks (%)**	**Arm Curl 10 wks**	**Ov-all 5 wks (%)**	**Ov-all 10 wks**
2	51	84	21	65	19	47	13	41	10	32	5	14	18	45	24	53
4	5	50	0	7	8	23	5	14	17	28	10	23	5	15	6	28
6	67	137	21	35	38	60	20	31	29	62	6	12	14	24	32	60
7	58	132	24	48	36	51	11	21	17	50	7	13	15	38	28	59
10	45	94	0	28	20	39	3	23	13	33	-3	6	6	18	16	43
11	0	40	2	28	4	16	0	50	0	30	0	2	5	36	1	30
16	15	32	8	15	8	22	10	24	22	36	5	8	9	18	11	24
17	25	61	25	36	18	31	16	26	33	42	0	10	36	68	22	40
19	30	52	6	8	18	37	5	24	32	46	0	15	23	45	17	33
20	41	93	20	30	39	45	19	35	10	33	26	35	0	9	53	77
Mean	**33.7**	**77.5**	**12.7**	**30.0**	**20.8**	**37.1**	**10.2**	**28.9**	**18.3**	**39.2**	**5.6**	**13.8**	**13.1**	**31.6**	**21.0**	**44.7**
± SEM	**7.1**	**11.7**	**3.3**	**5.6**	**4.1**	**4.5**	**2.2**	**3.4**	**3.4**	**3.4**	**2.6**	**3.0**	**3.4**	**5.7**	**4.7**	**5.4**

Table 14. Individual Lower Body Strength Gains

Subject (CHO)	**Leg Press wk 0 (kg)**	**Leg Press wk 5**	**Leg Press wk 10**	**Leg Curl wk 0 (kg)**	**Leg Curl wk 5**	**Leg Curl wk 10**	**Leg Ext wk 0 (kg)**	**Leg Ext wk 5**	**Leg Ext wk 10**
1	288.6	338.6	411.4	159.1	170.5	186.4	140.9	159.1	175
3	122.7	163.6	200	122.7	136.4	140.9	86.4	125	131.8
5	268.2	297.7	338.6	145.5	172.7	200	127.3	150	200
12	161.4	227.3	272.7	131.8	147.7	165.9	100	127.3	163.6
13	90.9	136.4	181.8	109.1	122.7	136.4	77.3	102.3	129.5
14	168.2	227.3	290.9	122.7	143.2	154.5	86.4	131.8	163.6
15	122.7	186.4	268.2	109.1	136.4	136.4	90.9	109.1	122.7
18	118.2	222.7	388.6	109.1	136.4	147.7	84.1	97.7	118.2
21	175	256.8	288.6	136.4	140.9	152.3	118.2	120.5	154.5
Mean	**168.4**	**228.5**	**186.3**	**127.3**	**145.2**	**157.8**	**101.3**	**124.5**	**151.0**
± SEM	**22.7**	**21.2**	**15.6**	**5.9**	**5.5**	**7.5**	**7.4**	**6.9**	**9.1**
Subject (MILK)	**Leg Press wk 0 (kg)**	**Leg Press wk 5**	**Leg Press wk 10**	**Leg Curl wk 0 (kg)**	**Leg Curl wk 5**	**Leg Curl wk 10**	**Leg Ext wk 0 (kg)**	**Leg Ext wk 5**	**Leg Ext wk 10**
2	236.4	356.8	434.1	154.5	186.4	254.5	129.5	154.5	190.9
4	245.5	256.8	368.2	127.3	127.3	136.4	109.1	118.2	134.1
6	136.4	227.3	322.7	109.1	131.8	147.7	90.9	125	145.5
7	114.8	181.8	265.9	95.5	118.2	140.9	88.6	120.5	134.1
10	156.8	227.3	304.5	122.7	122.7	156.8	127.3	152.3	177.3
11	229.5	229.5	320.5	122.7	125	156.8	129.5	134.1	150
16	213.6	245.5	281.8	118.2	127.3	136.4	113.6	122.7	138.6
17	197.7	247.7	318.2	134.1	168.2	181.8	125	147.7	163.6
19	209.1	272.7	318.2	147.7	156.8	159.1	118.2	139.8	161.4
20	122.7	172.7	236.4	113.6	136.4	147.7	100	138.6	145.5
Mean	**186.3**	**241.8**	**317.0**	**124.5**	**140**	**161.8**	**113.2**	**135.3**	**154.1**
± SEM	**15.6**	**16.1**	**17.3**	**5.6**	**7.2**	**11.1**	**4.9**	**4.2**	**6.0**

Table 15. Individual Upper Body Strength Gains

Subject (CHO)	Ben Pr wk 0 (kg)	Ben Pr wk 5	Ben Pr wk 10	Shoul Pr wk 0 (kg)	Shoul Pr wk 5	Shoul Pr wk 10	Lat Pull wk 0 (kg)	Lat Pull wk 5	Lat Pull wk 10	Arm Curl wk 0 (kg)	Arm Curl wk 5	Arm Curl wk 10
1	95.5	106.8	115.9	86.4	102.3	109.1	90.9	104.5	111.4	45.5	61.4	68.2
3	72.7	84.1	100	61.4	72.7	97.7	72.7	84.1	84.1	38.6	47.7	53.4
5	113.6	118.2	136.4	95.5	118.2	131.8	95.5	100	104.5	59.1	63.6	70.5
12	90.9	95.5	122.7	100	109.1	134.1	77.3	77.3	81.8	45.5	59.1	68.2
13	68.2	75	84.1	68.2	69.3	86.4	68.2	70.5	86.4	36.4	45.5	52.3
14	118.2	150	154.5	127.3	140.9	143.2	100	104.5	113.6	65.9	77.3	79.5
15	68.2	84.1	95.5	68.2	79.5	95.5	72.7	72.7	77.3	31.8	42.0	47.7
18	68.2	79.5	93.2	68.2	79.5	106.8	59.1	72.7	81.8	36.4	40.9	47.7
21	100	104.5	113.6	93.2	102.3	113.6	72.7	77.3	79.5	45.5	50	54.5
Mean	**88.4**	**99.7**	**112.9**	**85.4**	**97.1**	**113.1**	**78.8**	**84.9**	**91.2**	**45.0**	**54.2**	**60.2**
± SEM	**6.7**	**7.9**	**7.5**	**7.1**	**7.9**	**6.5**	**4.6**	**4.7**	**4.8**	**3.7**	**4.0**	**3.8**
Subject (MILK)	**Ben Pr wk 0 (kg)**	**Ben Pr wk 5**	**Ben Pr wk 10**	**Shoul Pr wk 0 (kg)**	**Shoul Pr wk 5**	**Shoul Pr wk 10**	**Lat Pull wk 0 (kg)**	**Lat Pull wk 5**	**Lat Pull wk 10**	**Arm Curl wk 0 (kg)**	**Arm Curl wk 5**	**Arm Curl wk 10**
2	104.5	118.2	147.8	113.6	125	150	100	104.5	113.6	50	59.1	72.7
4	95.5	100	109.1	81.8	95.5	104.5	68.2	75	84.1	45.5	47.7	52.3
6	79.5	95.5	104.5	77.3	100	125	77.3	81.8	86.4	47.7	54.5	59.1
7	63.6	70.5	77.3	54.5	63.6	81.8	68.2	72.7	77.3	29.5	34.1	40.9
10	79.5	81.8	97.7	68.2	77.3	90.9	72.7	70.5	77.3	28.6	40.9	45.5
11	104.5	104.5	156.8	104.5	104.5	136.4	97.7	97.7	100	50	52.3	68.2
16	93.2	102.3	115.9	82.8	100	111.4	86.4	90.9	93.2	50	54.5	59.1
17	86.4	100	109.1	81.8	109.1	115.9	93.2	93.2	102.3	50	68.2	84.1
19	95.5	100	118.2	93.2	122.7	136.4	90.9	90.9	104.5	50	61.4	72.7
20	77.3	92.0	104.5	68.2	75	90.9	77.3	97.7	104.5	50	50	54.5
Mean	**88.0**	**96.5**	**114.1**	**82.6**	**97.3**	**114.3**	**83.2**	**87.5**	**94.3**	**45.1**	**52.4**	**60.9**
± SEM	**4.1**	**4.1**	**7.3**	**5.6**	**6.4**	**7.2**	**3.8**	**3.7**	**4.0**	**2.7**	**3.1**	**4.3**

APPENDIX C:

Statistical Procedures and Results

A t-test was performed to detect differences between groups in body composition data. All other measures were analyzed by repeated measures analysis of variance (RMANOVA) to test for effect of group, time and group by time interaction. Significance was defined at the $p<0.05$ level.

Table 16. T-tests for Changes in Body Composition Data

	DF	**T**	**P**
Body Weight	17	-1.31	0.10
Lean Body Mass	17	-1.16	0.13
Body Fat	17	-0.70	0.25

Table 17. RM ANOVA Table for Body Weight

Variation	DF	DFE	SS	MS	MSE	F	P
Beverage	1		8.10	8.10		0.0179	0.895
Time	1		0.00057	0.00057		0.000142	0.991
Time*Beverage	1		6.88	6.88		1.70	0.209
Residual		17			4.04		

Table 18. RM ANOVA Table for Total Body Mass

Variation	DF	DFE	SS	MS	MSE	F	P
Beverage	1		9.66	9.66		0.0208	0.887
Time	1		0.702	0.702		0.174	0.682
Time*Beverage	1		5.11	5.11		1.269	0.276
Residual		17			4.03		

Table 19. RM ANOVA Table for Total Body Fat

Variation	DF	DFE	SS	MS	MSE	F	P
Beverage	1		23.17	23.17		0.218	0.646
Time	1		8.58	8.58		3.50	0.079
Time*Beverage	1		1.20	1.20		0.489	0.494
Residual		17			9.42		

Table 20. RM ANOVA Table for Percent Body Fat

Variation	DF	DFE	SS	MS	MSE	F	P
Beverage	1		43.23	43.23		0.749	0.399
Time	1		12.32	12.32		4.77	0.044
Time*Beverage	1		0.693	0.693		0.266	0.613
Residual		17			2.61		

Table 21. RM ANOVA Table for Total Lean Body Mass

Variation	DF	DFE	SS	MS	MSE	F	P
Beverage	1		2.27	2.27		0.0156	0.902
Time	1		13.83	13.83		14.17	0.002
Time*Beverage	1		1.35	1.35		1.38	0.256
Residual		17			0.976		

Table 22. RM ANOVA Table for Right Total Arm Lean Body Mass

Variation	DF	DFE	SS	MS	MSE	F	P
Beverage	1		0.0276	0.0276		0.0427	0.839
Time	1		0.105	0.105		4.15	0.057
Time*Beverage	1		0.0537	0.0537		2.12	0.163
Residual		17			0.0253		

Table 23. RM ANOVA Table for Left Total Arm Lean Body Mass

Variation	DF	DFE	SS	MS	MSE	F	P
Beverage	1		0.0135	0.0135		0.0161	0.901
Time	1		0.186	0.186		11.68	0.003
Time*Beverage	1		0.0464	0.0464		2.92	0.106
Residual		17			0.0159		

Table 24. RM ANOVA Table for Right Upper Arm Lean Body Mass

Variation	DF	DFE	SS	MS	MSE	F	P
Beverage	1		0.0741	0.0741		0.233	0.635
Time	1		0.0704	0.0704		6.52	0.021
Time*Beverage	1		0.0362	0.0362		3.34	0.085
Residual		17			0.0108		

Table 25. RM ANOVA Table for Left Upper Arm Lean Body Mass

Variation	DF	DFE	SS	MS	MSE	F	P
Beverage	1		0.0248	0.0248		0.0616	0.807
Time	1		0.102	0.102		7.70	0.013
Time*Beverage	1		0.0211	0.0211		1.59	0.224
Residual		17			0.0133		

Table 26. RM ANOVA Table for Right Forearm Lean Body Mass

Variation	DF	DFE	SS	MS	MSE	F	P
Beverage	1		0.0111	0.0111		0.147	0.706
Time	1		0.00352	0.00352		0.707	0.412
Time*Beverage	1		0.00178	0.00178		0.358	0.558

Residual		17			0.00498		

Table 27. RM ANOVA Table for Left Forearm Lean Body Mass

Variation	DF	DFE	SS	MS	MSE	F	P
Beverage	1		6.47	6.47		0.857	0.368
Time	1		6.82	6.82		0.960	0.341
Time*Beverage	1		6.60	6.60		0.929	0.349
Residual		17			7.106		

Table 28. RM ANOVA Table for Right Total Arm Body Fat

Variation	DF	DFE	SS	MS	MSE	F	P
Beverage	1		0.283	0.283		0.927	0.349
Time	1		0.0230	0.0230		2.42	0.138
Time*Beverage	1		0.0118	0.0118		1.24	0.281
Residual		17			0.00949		

Table 29. RM ANOVA Table for Left Total Arm Body Fat

Variation	DF	DFE	SS	MS	MSE	F	P
Beverage	1		0.142	0.142		0.478	0.499
Time	1		0.0587	0.0587		7.98	0.012
Time*Beverage	1		0.00234	0.00234		0.318	0.580
Residual		17			0.00735		

Table 30. RM ANOVA Table for Right Upper Arm Body Fat

Variation	DF	DFE	SS	MS	MSE	F	P
Beverage	1		0.145	0.145		0.908	0.354
Time	1		0.0198	0.0198		3.62	0.074
Time*Beverage	1		0.00296	0.00296		0.542	0.471
Residual		17			0.00545		

Table 31. RM ANOVA Table for Left Upper Arm Body Fat

Variation	DF	DFE	SS	MS	MSE	F	P
Beverage	1		0.0688	0.0688		0.391	0.540
Time	1		0.0259	0.0259		3.93	0.064
Time*Beverage	1		0.000178	0.000178		0.027	0.872
Residual		17			0.0066		

Table 32. RM ANOVA Table for Right Forearm Body Fat

Variation	DF	SS	MS	F	P
Beverage	1	0.0222	0.0222	0.823	0.377
Time	1	0.000156	0.000156	0.0624	0.806
Time*Beverage	1	0.00276	0.00276	1.10	0.308
Residual	17		0.0025		

Table 33. RM ANOVA Table for Left Forearm Body Fat

Variation	DF	SS	MS	F	P
Beverage	1	0.0110	0.0110	0.606	0.447
Time	1	0.00518	0.00518	3.93	0.064
Time*Beverage	1	0.00196	0.00196	1.49	0.239
Residual	17		0.00132		

Table 34. RM ANOVA Table for Right Total Leg Lean Body Mass

Variation	DF	SS	MS	F	P
Beverage	1	0.366	0.366	0.0761	0.786
Time	1	0.595	0.595	13.91	0.002
Time*Beverage	1	0.109	0.109	2.55	0.129
Residual	17		0.0428		

Table 35. RM ANOVA Table for Left Total Leg Lean Body Mass

Variation	DF	SS	MS	F	P
Beverage	1	0.216	0.216	0.0473	0.830
Time	1	0.438	0.438	10.38	0.005
Time*Beverage	1	0.228	0.228	5.39	0.033
Residual	17		2.143		

Table 36. RM ANOVA Table for Right Upper Leg Lean Body Mass

Variation	DF	SS	MS	F	P
Beverage	1	0.171	0.171	0.0603	0.809
Time	1	0.487	0.487	12.13	0.003
Time*Beverage	1	0.0658	0.0658	1.64	0.218
Residual	17		0.0401		

Table 37. RM ANOVA Table for Left Upper Leg Lean Body Mass

Variation	DF	SS	MS	F	P
Beverage	1	0.179	0.179	0.0632	0.804
Time	1	0.362	0.362	8.34	0.010
Time*Beverage	1	0.122	0.122	2.80	0.112
Residual	17		0.0435		

Table 38. RM ANOVA Table for Right Lower Leg Lean Body Mass

Variation	DF	SS	MS	F	P
Beverage	1	0.0373	0.0373	0.112	0.742
Time	1	0.00538	0.00538	1.63	0.218
Time*Beverage	1	0.00600	0.00600	1.82	0.195
Residual	17		0.0033		

Table 39. RM ANOVA Table for Left Lower Leg Lean Body Mass

Variation	DF	SS	MS	F	P
Beverage	1	0.00198	0.00198	0.00746	0.932
Time	1	0.00354	0.00354	0.468	0.503
Time*Beverage	1	0.0164	0.0164	2.16	0.160
Residual	17		0.00757		

Table 40. RM ANOVA Table for Right Total Leg Body Fat

Variation	DF	SS	MS	F	P
Beverage	1	1.34	1.34	0.284	0.601
Time	1	0.448	0.448	6.08	0.025
Time*Beverage	1	0.0975	0.0975	1.32	0.266
Residual	17		0.0737		

Table 41. RM ANOVA Table for Left Total Leg Body Fat

Variation	DF	SS	MS	F	P
Beverage	1	0.953	0.953	0.186	0.672
Time	1	0.0674	0.0674	0.798	0.384
Time*Beverage	1	0.00296	0.00296	0.0350	0.854
Residual	17		0.0844		

Table 42. RM ANOVA Table for Right Upper Leg Body Fat

Variation	DF	SS	MS	F	P
Beverage	1	0.469	0.469	0.179	0.677
Time	1	0.301	0.301	5.87	0.027
Time*Beverage	1	0.123	0.123	2.41	0.139
Residual	17		0.0512		

Table 43. RM ANOVA Table for Left Upper Leg Body Fat

Variation	DF	SS	MS	F	P
Beverage	1	0.314	0.314	0.115	0.739
Time	1	0.0116	0.0116	0.161	0.693
Time*Beverage	1	0.00244	0.00244	0.0339	0.856
Residual	17		0.0719		

Table 44. RM ANOVA Table for Right Lower Leg Body Fat

Variation	DF	SS	MS	F	P
Beverage	1	0.237	0.237	0.691	0.417
Time	1	0.0115	0.0115	1.80	0.197
Time*Beverage	1	0.000632	0.000632	0.0992	0.757
Residual	17		0.00064		

Table 45. RM ANOVA Table for Left Lower Leg Body Fat

Variation	DF	SS	MS	F	P
Beverage	1	0.172	0.172	0.422	0.525
Time	1	0.0226	0.0226	3.73	0.070
Time*Beverage	1	0.0000445	0.0000445	0.00734	0.933
Residual	17		0.0061		

Table 46. RM ANOVA Table for Total Testosterone Concentrations

Variation	DF	SS	MS	F	P
Beverage	1	0.108	0.108	0.0336	0.857
Time	1	11.63	11.63	18.73	<0.001
Time*Beverage	1	0.207	0.207	0.333	0.571
Residual	17		0.621		

Table 47. RM ANOVA Table for Free Testosterone Concentrations

Variation	DF	SS	MS	F	P
Beverage	1	11.05	11.05	0.205	0.656
Time	1	94.93	94.93	4.51	0.049
Time*Beverage	1	6.77	6.77	0.321	0.578
Residual	17		21.07		

Table 48. RM ANOVA Table for IGF-1 Concentrations

Variation	DF	SS	MS	F	P
Beverage	1	64920.4	64920.4	2.16	0.160
Time	1	3513.0	3513.0	0.696	0.416
Time*Beverage	1	1236.3	1236.3	0.245	0.627
Residual	17		5048.02		

Table 49. RM ANOVA Table for Insulin Concentrations

Variation	DF	SS	MS	F	P
Beverage	1	24.44	24.44	0.457	0.509
Time	1	194.14	194.14	9.30	0.008
Time*Beverage	1	0.0400	0.0400	0.00192	0.966
Residual	16		21.506		

Table 50. RM ANOVA Table for Percent Protein Intake

Variation	DF	SS	MS	F	P
Beverage	1	31.07	31.07	1.02	0.330
Time	3	28.18	9.40	0.434	0.730
Time*Beverage	3	118.18	39.40	1.82	0.157
Residual	45		21.642		

Table 51. RM ANOVA Table for Total Protein Intake

Variation	DF	SS	MS	F	P
Beverage	1	436.9	436.9	0.174	0.683
Time	3	1051.6	350.5	0.449	0.719
Time*Beverage	3	1451.9	484.0	0.620	0.605
Residual	45		780.134		

Table 52. RM ANOVA Table for Protein Intake (g/kg)

Variation	DF	SS	MS	F	P
Beverage	1	0.00644	0.00644	0.0165	0.899
Time	1	0.00787	0.00787	0.0300	0.865
Time*Beverage	1	0.00283	0.00283	0.0108	0.919
Residual	15		0.262		

Table 53. RM ANOVA Table for Percent Carbohydrate Intake

Variation	DF	SS	MS	F	P
Beverage	1	42.47	42.47	0.120	0.734
Time	3	20.30	6.77	0.153	0.927
Time*Beverage	3	42.18	14.06	0.319	0.812
Residual	45		44.123		

Table 54. RM ANOVA Table for Total Carbohydrate Intake

Variation	DF	SS	MS	F	P
Beverage	1	6261.0	6261.0	0.271	0.610
Time	3	2398.3	799.4	0.108	0.955
Time*Beverage	3	14606.2	4868.7	0.659	0.581
Residual	45		7384.763		

Table 55. RM ANOVA Table for Percent Fat Intake

Variation	DF	SS	MS	F	P
Beverage	1	171.4	171.4	1.01	0.331
Time	3	88.97	29.66	0.784	0.509
Time*Beverage	3	12.27	4.09	0.108	0.955
Residual	45		37.812		

Table 56. RM ANOVA Table for Total Fat Intake

Variation	DF	SS	MS	F	P
Beverage	1	1410.9	1410.9	0.448	0.514
Time	3	696.5	232.2	0.243	0.866
Time*Beverage	3	523.1	954.4	0.183	0.908
Residual	45		954.377		

Table 57. RM ANOVA Table for Calorie Intake

Variation	DF	SS	MS	F	P
Beverage	1	41813.5	41813.5	0.0465	0.832
Time	3	65686.9	21895.6	0.0643	0.978
Time*Beverage	3	825911.4	275303.8	0.809	0.496
Residual	45		340494.7		

Table 58. RM ANOVA Table for Total Calcium Intake

Variation	DF	SS	MS	F	P
Beverage	1	1792.4	1792.4	0.00389	0.951
Time	3	594628.4	198209.5	2.71	0.056
Time*Beverage	3	19148.5	6382.8	0.0873	0.967
Residual	45		73099.359		

Table 59. RM ANOVA Table for Leg Press Strength Gains

Variation	DF	SS	MS	F	P
Beverage	1	22873.9	22873.9	0.493	0.492
Time	2	752335.0	376167.5	102.8	<0.001
Time*Beverage	2	1228.9	614.5	0.168	0.846
Residual	34		3657.793		

Table 60. RM ANOVA Table for Leg Curl Strength Gains

Variation	DF	SS	MS	F	P
Beverage	1	118.6	118.6	0.0181	0.894
Time	2	52742.6	26371.3	43.18	<0.001
Time*Beverage	2	1037.3	518.7	0.849	0.437
Residual	34		610.719		

Table 61. RM ANOVA Table for Leg Extension Strength Gains

Variation	DF	SS	MS	F	P
Beverage	1	5005.8	5005.8	1.00	0.330
Time	2	94212.8	47106.4	114.58	<0.001
Time*Beverage	2	1041.7	520.9	1.27	0.295
Residual	34		411.118		

Table 62. RM ANOVA Table for Bench Press Strength Gains

Variation	DF	SS	MS	F	P
Beverage	1	47.28	47.28	0.00921	0.925
Time	2	29836.7	14918.3	65.74	<0.001
Time*Beverage	2	235.8	117.9	0.520	0.599
Residual	34		226.927		

Table 63. RM ANOVA Table for Shoulder Press Strength Gains

Variation	DF	SS	MS	F	P
Beverage	1	16.96	16.96	0.00283	0.958
Time	2	40878.2	20439.1	121.8	<0.001
Time*Beverage	2	202.7	101.4	0.604	0.552
Residual	34		167.838		

Table 64. RM ANOVA Table for Lateral Pull-down Strength Gains

Variation	DF	SS	MS	F	P
Beverage	1	795.4	795.4	0.342	0.567
Time	2	6364.9	3182.5	39.16	<0.001
Time*Beverage	2	36.85	18.43	0.227	0.798
Residual	34		81.269		

Table 65. RM ANOVA Table for Arm Curl Strength Gains

Variation	DF	SS	MS	F	P
Beverage	1	0.00487	0.00487	0.0000031	0.999
Time	2	10353.3	5176.6	66.53	<0.001
Time*Beverage	2	125.19	62.59	0.804	0.456
Residual	34		77.813		

Table 66. RM ANOVA Table for Leg Press Percent Strength Change

Variation	DF	SS	MS	F	P
Beverage	1	0.0867	0.0867	0.355	0.559
Time	1	1.84	1.84	40.39	<0.001
Time*Beverage	1	0.000177	0.000177	0.00389	0.951
Residual	17		0.0456		

Table 67. RM ANOVA Table for Leg Curl Percent Strength Change

Variation	DF	SS	MS	F	P
Beverage	1	0.00318	0.00318	0.136	0.717
Time	1	0.172	0.172	33.52	<0.001
Time*Beverage	1	0.0138	0.0138	2.70	0.119
Residual	17		0.00512		

Table 68. RM ANOVA Table for Leg Extension Percent Strength Change

Variation	DF	SS	MS	F	P
Beverage	1	0.0454	0.0454	0.872	0.363
Time	1	0.341	0.341	60.57	<0.001
Time*Beverage	1	0.00616	0.00616	1.09	0.310
Residual	17		0.00563		

Table 69. RM ANOVA Table for Bench Press Percent Strength Change

Variation	DF	SS	MS	F	P
Beverage	1	0.00163	0.00163	0.158	0.696
Time	1	0.284	0.284	52.13	<0.001
Time*Beverage	1	0.00280	0.00280	0.514	0.483
Residual	17		0.00545		

Table 70. RM ANOVA Table for Shoulder Press Percent Strength Change

Variation	DF	SS	MS	F	P
Beverage	1	0.0176	0.0176	0.921	0.351
Time	1	0.419	0.419	65.47	<0.001
Time*Beverage	1	0.000009	0.000009	0.00142	0.970
Residual	17		0.00641		

Table 71. RM ANOVA Table for Lateral Pull-down Percent Strength Change

Variation	DF	SS	MS	F	P
Beverage	1	0.00610	0.00610	0.397	0.537
Time	1	0.0657	0.0657	40.88	<0.001
Time*Beverage	1	0.0000016	0.0000016	0.00101	0.975
Residual	17		0.00161		

Table 72. RM ANOVA Table for Arm Curl Percent Strength Change

Variation	DF	SS	MS	F	P
Beverage	1	0.0367	0.0367	1.08	0.313
Time	1	0.259	0.259	81.95	<0.001
Time*Beverage	1	0.00411	0.00411	1.30	0.270
Residual	17		0.00316		

Table 73. RM ANOVA Table for Overall Percent Strength Change

Variation	DF	SS	MS	F	P
Beverage	1	0.000596	0.000596	0.0157	0.902
Time	1	0.494	0.494	140.24	<0.001
Time*Beverage	1	0.000513	0.000513	0.146	0.708
Residual	17		0.00352		

Table 74. RM ANOVA Table for Right Arm Circumference

Variation	DF	SS	MS	F	P
Beverage	1	18.44	18.44	0.599	0.450
Time	1	3.83	3.83	5.25	0.035
Time*Beverage	1	0.0702	0.0702	0.0962	0.760
Residual	17		0.731		

Table 75. RM ANOVA Table for Left Arm Circumference

Variation	DF	SS	MS	F	P
Beverage	1	13.95	13.95	0.412	0.529
Time	1	4.63	4.63	6.44	0.021
Time*Beverage	1	0.463	0.463	0.645	0.433
Residual	17		0.719		

Table 76. RM ANOVA Table for Right Leg Circumference

Variation	DF	SS	MS	F	P
Beverage	1	7.23	7.23	0.0968	0.759
Time	1	3.95	3.95	3.02	0.100
Time*Beverage	1	1.79	1.79	1.37	0.258
Residual	17		1.307		

Table 77. RM ANOVA Table for Left Leg Circumference

Variation	DF	SS	MS	F	P
Beverage	1	9.77	9.77	0.132	0.721
Time	1	4.78	4.78	3.56	0.076
Time*Beverage	1	1.59	1.59	1.19	0.291
Residual	17		1.340		

Table 78. RM ANOVA Table for Chest Circumference

Variation	DF	SS	MS	F	P
Beverage	1	15.66	15.66	0.128	0.725
Time	1	20.72	20.72	3.62	0.074
Time*Beverage	1	4.66	4.66	0.813	0.380
Residual	17		5.727		

Table. 79 Correlation Analysis for Changes in Measurements for MILK

MILK	Bench Press	Leg Press	Body Fat	Lean Body Mass	Total Testos	Free Testos	Insulin	Kcal Intake	Protein Intake
Bench Press	X	X	X	r= -0.29	r= 0.08	r= 0.41	r= 0.60	r= 0.13	r= -0.13
Leg Press	X	X	X	r= 0.17	r= -0.46	r= 0.19	r= 0.31	r= 0.42	r= -0.25
Body Fat	X	X	X	X	r= -0.20	r= 0.16	r= 0.004	r= 0.31	r= -0.52
Lean Body Mass	r= -0.29	r= 0.17	X	X	r=- 0.68	r= -0.29	r= -0.28	r= 0.07	r= -0.20
Total Testost	r= 0.08	r= -0.46	r= -0.20	r= -0.68	X	X	X	r= -0.17	r= -0.05
Free Testost	r= 0.41	r= 0.19	r= 0.16	r= -0.29	X	X	X	r= 0.08	r= 0.09
Insulin	r= 0.60	r= 0.31	r= 0.004	r= -0.28	X	X	X	r= 0.51	r= -0.14
Kcal Intake	r= 0.13	r= 0.42	r= 0.31	r= 0.07	r= -0.17	r= 0.08	r= 0.51	X	X
Protein Intake	r= -0.13	r= -0.25	r= -0.52	r= -0.20	r= -0.05	r= 0.09	r= -0.14	X	X

Table 80. Correlation Analysis for Changes in Measurements for CHO

CHO	Bench Press	Leg Press	Body Fat	Lean Body Mass	Total Testos	Free Testos	Insulin	Kcal Intake	Protein Intake
Bench Press	X	X	X	r= 0.40	r= -0.11	r= -0.50	r= 0.07	r= -0.38	r= 0.08
Leg Press	X	X	X	r= 0.20	r= -0.54	r= -0.25	r= -0.35	r= -0.01	r= -0.10
Body Fat	X	X	X	X	r= -0.60	r= -0.06	r= 0.26	r= 0.45	r= -0.53
Lean Body Mass	r= 0.40	r= 0.20	X	X	r= -0.22	r= -0.18	r= -0.21	r= 0.28	r= -0.14
Total Testost	r= -0.11	r= -0.54	r= -0.60	r= -0.22	X	X	X	r= -0.21	r= -0.48
Free Testost	r= -0.50	r= -0.25	r= -0.06	r= -0.18	X	X	X	r= -0.10	r= -0.19
Insulin	r= 0.07	r= -0.35	r= 0.26	r= -0.21	X	X	X	r= 0.38	r= -0.07
Kcal Intake	r= -0.38	r= -0.01	r= 0.45	r= 0.28	r= -0.21	r= -0.10	r= 0.38	X	X
Protein Intake	r= 0.08	r= -0.10	r= -0.53	r= -0.14	r= -0.48	r= -0.19	r= -0.07	X	X

APPENDIX D:

Informed Consent and Health History Questionnaire

SUPPLEMENTARY QUESTIONS

Food Habits and Allergies

1. Are you allergic to any foods? ____ If yes, which ones?

2. Are you on any kind of special diet? ____ If so, what kind?

1. Do you take any dietary supplements?_____ If so, what kind and how often?

2. Has your weight been stable over the past year?____ If not, how has it changed?

Drug Allergies

3. Are you aware of any allergies you have to any drugs? ____ If yes, which ones?

4. Have you ever received Novocaine at the dentist's office or other local (injected into skin) anesthetic? _____.

If yes, did you have any allergic reaction to this?_____

Comfort with procedures

5. Do you have a fear of needles or having blood withdrawn?

8. Is there anything about the muscle sampling procedures that particularly concerns you? Explain.

VIRGINIA TECH LABORATORY FOR HEALTH AND EXERCISE SCIENCE
MEDICAL AND HEALTH HISTORY

Name: _____ Age: _____ Birth Date: _____

Address: _____ e-mail: _____

Phone Numbers: Home: _____ Work :_____

Summer Address: _____
_____

Phone Number (during Winter Break): _____

Person to Contact in Case of an Emergency: _____

Relationship: _____Phone: _____

Primary Care Physician: _____Phone: _____

Medical Insurance Carrier: _____

Are you employed by Virginia Tech? _____

Current Body Weight:_____

MEDICAL HISTORY

Please indicate any current or previous conditions or problems you have experienced or have been told by a physician you have had:

	Yes	**No**
Heart disease or any heart problems:	_____	_____
Rheumatic Fever:	_____	_____
Respiratory disease or breathing problems (e.g. asthma):	_____	_____
Circulation problems:	_____	_____
Kidney disease or problems:	_____	_____
Urinary problems:	_____	_____
Musculoskeletal problems:	_____	_____
(i.e. Orthopedic injuries, osteoporosis)		
Fainting and Dizziness:	_____	_____
High Cholesterol:	_____	_____
Diabetes:	_____	_____
Thyroid problems:	_____	_____
Mental illness:	_____	_____
Hypoglycemia:(i.e. low blood sugar)	_____	_____
Epilepsy or seizures:	_____	_____
Blood clotting problems (e.g. hemophilia**):**	_____	_____
Liver disorders (e.g. hepatitis B)	_____	_____

If you answered "yes" to any of the previous questions, please indicate the date and describe:
_____
_____
_____
_____

Please list any hospitalizations/operations/recent illnesses (type/date):
_____
_____
_____
_____
_____

	Yes	**No**
Have you ever been diagnosed as having high blood pressure?	_____	_____
Are you currently being treated for high blood pressure?	_____	_____

If "yes", please explain:
_____
_____
_____

Please list all medications (prescription and over-the-counter) you are currently taking or have taken in the past week:
_____
_____
_____

For what reason(s) are you taking this medication?
_____
_____
_____

Health Habits

	Yes	**No**
Do you drink alcoholic beverages?	_____	_____
How many drinks per week? _____		
Do you smoke cigarettes?	_____	_____
Packs per day: _____		
	Yes	**No**
Do you engage in regular exercise?	_____	_____

If "yes", please list:

Activity	**Frequency (times per week)**	**Duration (minutes)**
_____	_____	_____
_____	_____	_____
_____	_____	_____

Do you ever faint, experience shortness of breath or chest discomfort with exertion? _____

If "yes", please explain: _____
_____

Are there any orthopedic limitations you have that may restrict your ability to perform exercise and if "yes", please explain:
_____
_____
_____

Family History

Has anyone in your family been diagnosed or treated for any of the following?

	Yes	**No**	**Relationship**	**Age**
Heart attack	____	____	_____	____
Heart disease	____	____	_____	____
High blood pressure	____	____	_____	____
Stroke	____	____	_____	____
Kidney disease	____	____	_____	____
Diabetes	____	____	_____	____

Schedule Spring 2001 semester (indicate those times you have classes, work etc that you CANNOT be involved in testing or exercise training):

	Mon	*Tue*	*Wed*	*Thursday*	*Fri*
6:00-7:00am					
7:00-8:00					
8:00-9:00					
9:00-10:00					
10:00-11:00					
11:00-12:00					
12:00-1:00					
1:00-2:00					
2:00-3:00					
3:00-4:00					
4:00-5:00					
5:00-6:00					
6:00-7:00					
7:00-8:00					

Any explanation required for above _____
_____
_____

Please sign to indicate that the above information is correct:

_____ _____ _____

Print name Signature Date

APPENDIX E:

Institutional Review Board

Informed Consent for Participants of Investigative Projects
Department of Human Nutrition, Foods, and Exercise
Virginia Tech

TITLE: The Role of Recovery Beverages on Training Adaptations to Resistance Exercise. **PHASE II.**

PRINCIPAL INVESTIGATOR: Janet Walberg Rankin, Ph.D., graduate students: Lauren Goldman and Michael Puglisi

PURPOSE:

Some people consume special beverages after resistance exercise to enhance recovery after the workout. This study will examine the effect of several different beverages on muscle protein synthesis and breakdown that results from consumption of these drinks after a strenuous resistance training workout. In addition, we will determine whether individuals get more muscle mass or strength gains with one supplement over the other when they participate in regular resistance weight training.

General Design

The study will last approximately 12 weeks with the first week being baseline testing of strength, diet and body composition. The next 10 weeks will include a resistance training program 3 days/wk. We will give you a beverage to consume after each workout..

Once at the first week of the training and once during the last week of training, we will ask you to come to our laboratory in the morning without eating breakfast. We will take a small sample of your muscle as well as a blood sample while you are resting. Then, we will ask you to do a strenuous resistance training workout designed for you based on your muscle strength. It will include 5 sets of 8 repetitions at 80% of your maximal strength of leg extension and leg press. We will give you a beverage to consume as soon as you are done. We will take another sample of your muscle and blood at 1 hour after you complete the workout.

Body Composition: We will use two methods to estimate your body composition (body fat and lean tissue). One method uses a machine called DEXA to measure your body fat and lean body mass. This involves lying still on a flat bed for about 15 minutes while a beam passes over your body. This procedure uses 2 low energy X rays to determine your body fat. You will not feel anything during the procedure but need to remain very still. The second method for body composition estimation is bioelectric impedance. Measurements will be taken by three different devices, one after the other. You will remove your right sock and shoe, all jewelry and any metal objects, then you will have your hand and foot gently cleaned with an alcohol pad, after which four small wires will be attached to your hand and foot by a sticky pad called an electrode. A small, undetectable electrical signal will be sent through these wires through your body by the bioelectrical impedance analyzer. The resistance of your body to this signal will provide an estimate of body water, lean mass, and percent body fat. The measurement by each device will last less than 10 seconds in duration, and measurement by all three devices will take approximately 5 - 10 minutes.

1 Repetition Maximum (1RM)-

Prior to the start of the strength training program and at the end of the program, we will test your maximal strength for eight lifts. This will involve warming up with a weight you think you can lift about 10 times, resting, then progressively trying heavier weights until you can only lift the weight one time.

Muscle Samples
Since aspirin reduces blood clotting, you should not take aspirin for 24 h prior to having this procedure. A small sample of your thigh muscle will be taken just above the knee and to the outside of your leg. The area will be shaved and cleaned. A local anesthetic will be injected to the area (will feel like bee sting) to numb it. A half inch incision will be made with a scalpel after which a hollow needle will be inserted into the incision. A small piece of muscle will be removed with the needle (less than half the size of a pencil eraser). Some people feel nothing at all while others feel cramping or pressure when the sample is removed. After the needle is removed, we will apply pressure and then cold to the incision for about 20 minutes. The incision will be closed with a steri-strip (similar to a band-aid) and will be covered with a pressure wrap. The pressure bandage should be left on for about 8 hours and the steri-strips should remain on for about 3 days. You should not "baby" the leg; using it will prevent excessive stiffness. The incision may be sore for a few days as it heals. It is important to keep the area clean. You may take over the counter pain medication after having the muscle sample procedure if you feel that it is necessary. You will be provided with a written handout containing instructions for treatment of the biopsy incision as well as contact phone numbers for the physician involved in the study and the principal investigator. We want you to call both these individuals immediately if you have a concern about the biopsy incision or experience any adverse effects from the procedure. The incision will close and begin healing within a few days but a small scar will remain. You will have a total of 4 scars (2 on each thigh) at the end of the study. We will show you a photo of a scar from a former subject. The muscle sample we remove will be frozen and later analyzed for indicators of muscle protein synthesis. The biopsy procedure lasts about 30 minutes.

The biopsy procedure will be performed by a Certified Medical Laboratory Technician experienced in the procedure. In addition, a physician will be available in case of emergency. We have not had anyone who required any medical attention following muscle biopsies in the past. Over 200 muscle biopsies have been performed in previous studies.

Blood Samples
You will have three blood samples taken on the day of the resistance exercise test at the beginning and again at the end of the training program. The amount in each sample is about 2 teaspoons.

Urine Collections
You will be asked to collect all the urine you produce for a total of 4 days (2 days at the beginning and 2 days at the end) throughout the experiment. We will provide you with plastic containers to use to collect and store the urine over the day. You should bring it in to us in the morning and we will provide you with new bottles. We will measure a factor in the urine that indicates muscle protein breakdown.

SUBJECT RESPONSIBILITIES

1. Participate in the regular resistance training sessions 3 times per week for 10 weeks with a partner at the Virginia Tech Recreation Center.
2. Consume the provided beverage after each workout session.
3. Refrain from taking any other nutritional supplements without checking first with the experimenters.
4. Give maximal effort on performance tests.

5. Come to the resistance training test in a fasted condition (nothing to eat since the evening before) without having consumed any alcoholic or caffeinated beverages the night before or that morning.
6. Inform the experimenters if you experience any unusual symptom from any of the testing or training.
7. Inform the researchers of any known medical conditions or allergies you are aware of prior to the study as well as any transmittable diseases acquired during the study.
8. Refrain from taking aspirin for 24 hours prior to the muscle sampling procedures (to reduce chance of excess bleeding during the procedures).
9. You must remain in the laboratory for at least 20 minutes after the muscle sampling.
10. Come to the laboratory for the two days after your muscle biopsies so that we can insure they are healing correctly.

RISKS OF PARTICIPATION

1. Fatigue, muscle soreness, muscle strains or pulls may result from the resistance exercise. We will show you proper form to reduce the chance of serious injury.
2. Infection, bruising, muscle soreness from the blood and muscle sampling. The procedures will be conducted by an experienced technician. Universal precautions will be taken such as use of gloves when handling tissue samples. You blood will be screened for HIV if there is accidental exposure of an experimenter with your blood or muscle.
3. An allergic reaction is possible to the injection of local anesthetic prior to the muscle sampling. It is important to tell us if you have ever had an allergic reaction to novocaine or any other anesthetic.
4. The University will not be responsible for any medical expenses you may have unless the University has been negligent.
5. The amount of radiation exposure from the DEXA scan is very low and is about $1/1000^{th}$ of the normal radiation exposure you receive due to normal background radiation from the environment over a year. The exposure is much less than for most X ray tests you would receive at the hospital; for example it is about $1/20^{th}$ of the exposure received during a normal chest X ray. Increased exposure to radiation is associated with increased risk of tumors and cancer. However, the amount of radiation exposure from this scan is less than that acquired during a cross country flight. The amount of radiation in the scan is not expected to significantly increase your risk of cancer but this can not be quantified.

BENEFITS OF PARTICIPATION

Your participation will provide you with:

1. Data on your body composition and muscle strength.
2. A free supervised resistance training program individually designed for you.

COMPENSATION

A total of $200 for full completion of the study. If you complete less than the total study, your payment will be partial; $20 for completion of the baseline testing, $5 for each week of resistance training.

ANOYNMITY AND CONFIDENTIALITY

The data from this study will be kept strictly confidential. No data will be released to anyone but those working on the project without your written permission. Data will be identified by subject numbers, without anything to identify subjects by name.

FREEDOM TO WITHDRAW

You are free to withdraw at any time from the study for any reason. Circumstances may come up that the researcher will determine that you should not continue as a subject in the study. For example, lack of compliance to diet or exercise, failure to attend testing sessions and illness could be reasons to have the researchers stop your participation in the study.

APPROVAL OF RESEARCH

This research has been approved, as required, by the Institutional Review Board for Research Involving Human Subjects at Virginia Tech, and by the Department of Human Nutrition, Foods, and Exercise. You will receive a copy of this form to take with you.

SUBJECT PERMISSION

I have read the informed consent and fully understand the procedures and conditions of the project. I have had all my questions answered, and I hereby give my voluntary consent to be a participant in this research study. I agree to abide by the rules of the project. I understand that I may withdraw from the study at any time.

If I have questions, I will contact:

- Principal Investigator: Janet Walberg Rankin, Professor, Department of Human Nutrition, Foods, and Exercise. 231-6355
- Chairman, Institutional Review Board for Research Involving Human Subjects:David Moore, 231-4991

Name of Subject (please print)_____

APPENDIX F:

Dairy Frequency Form

FOOD FREQUENCY FORM

This form is to help us see how much dairy you consume on a normal basis. This includes eating the food by itself, or including it in a recipe (ex: macaroni and cheese). If you have the specified food daily, only use the daily column, and show how many times a day you eat that food. If you consume a food less often than 1 time per day, choose either the weekly or monthly column, depending on which best describes your intake of that food. If you never eat the specified food, only use the never column.

Do not use different columns for the same food.

	Daily (how many servings/day)	**Weekly** (how many servings/week)	**Monthly** (how many servings/month)	**Never**
Milk (8 oz)				
Cheese (1 oz, 6 Tbsp)				
Cottage Cheese (1/2 cup)				
Pudding/Custard (1/2 cup)				
Ice cream/ Frozen Yogurt (1 cup)				
Yogurt (1 cup)				
Macaroni and Cheese (1/2 cup)				
Pizza (1 slice)				

FOOD FREQUENCY FORM-Bad Example

This form is to help us see how much dairy you consume on a normal basis. This includes eating the food by itself, or including it in a recipe (ex: macaroni and cheese). If you have the specified food daily, only use the daily column, and show how many times a day you eat that food. If you consume a food less often than 1 time per day, choose either the weekly or monthly column, depending on which best describes your intake of that food. If you never eat the specified food, only use the never column.

Do not use different columns for the same food.

	Daily (how many servings/day)	**Weekly** (how many servings/week)	**Monthly** (how many servings/month)	**Never**
Milk (8 oz)	**2**	**14**	**56**	**0**
Cheese (1 oz, 6 Tbsp)	**1**	**7**	**28**	**0**
Cottage Cheese (1/2 cup)	**0**	**0**	**2**	**0**
Pudding/Custard (1/2 cup)	**0**	**0**	**1**	**0**
Ice cream/ Frozen Yogurt (1 cup)	**0**	**0**	**1**	**0**
Yogurt (1 cup)	**0**	**0**	**0**	**0**
Macaroni and Cheese (1/2 cup)	**0**	**0**	**4**	**0**
Pizza (1 slice)	**0**	**2**	**8**	**0**

FOOD FREQUENCY FORM-Good Example

This form is to help us see how much dairy you consume on a normal basis. This includes eating the food by itself, or including it in a recipe (ex: macaroni and cheese). If you have the specified food daily, only use the daily column, and show how many times a day you eat that food. If you consume a food less often than 1 time per day, choose either the weekly or monthly column, depending on which best describes your intake of that food. If you never eat the specified food, only use the never column.

Do not use different columns for the same food.

	Daily (how many servings/day)	**Weekly** (how many servings/week)	**Monthly** (how many servings/month)	**Never**
Milk (8 oz)	**2**			
Cheese (1 oz, 6 Tbsp)	**1**			
Cottage Cheese (1/2 cup)			**2**	
Pudding/Custard (1/2 cup)			**1**	
Ice cream/ Frozen Yogurt (1 cup)			**1**	
Yogurt (1 cup)				**0**
Macaroni and Cheese (1/2 cup)			**4**	
Pizza (1 slice)		**2**		

APPENDIX G:

Log Sheets

BEVERAGE CONSUMPTION

Subject:_____

DATE	TIME START	TIME FINISH

Comments:_____
_____
_____
_____

GIRTH MEASUREMENTS

Subject:_____ Date:_____

ARM:

Point of measurement:
Right: _____
Left: _____

Measurement-left (cm): _____

Measurement-right (cm): _____

LEG:

Point of measurement:
Right: _____
Left: _____

Measurement-left (cm): _____

Measurement-right (cm): _____

CHEST:

SUBJECT 1- RM LOG SHEET

Subject: _____ Date: _____

Beverage: _____

Height: _____

Body Weight: _____

TRIAL	BP-		SP-		Lat P-		AC-		Leg P-		LE-		LC-	
	R	W	R	W	R	W	R	W	R	W	R	W	R	W
1														
2														
3														
4														
5														
6														
1-RM														
1														
2														
3														
4														
5														
6														
1-RM														

NOTES:_____
_____
_____
_____

WEEKLY RT LOG SHEET

Subject:_____ **Time:_____**

Date	Leg Press		Leg Curl		Leg Ext		Lat Pull		Bench Pr		Arm Curl		Arm Ext		Trainer
	Wt	Set/Rep	Wt	Set/Rep	Wt	Set/Rep	Wt	Set/Rep	Wt	Set/Rep	Wt	Set/Rep	Wt	Set/Rep	

Comments:

_____

_____

_____

_____

_____

_____

APPENDIX H:

Recruitment Flyer

Nutrition and Exercise Research Study

Dept. Human Nutrition, Foods, and Exercise
338 Wallace Hall
Virginia Tech
Blacksburg VA 24061

Wanted:

Males, 18 – 25 years old
Available Spring Semester

Will involve:

- Total of 12 weeks
- Exercise training program
- Blood samples
- Muscle samples
- Urine sample

Will get:

- $200
- Strength Analysis
- Body Composition Analysis
- Personal exercise program

TO SEE IF YOU QUALIFY, contact Lauren Goldman at lgoldman@vt.edu

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Appendix I:

Instructions Given to Subjects

Instruction for DXA Scans

DXA stands for Dual Energy X-ray Absorptiometry and measures how much mineral is in a specific area of bone. This DXA machine can measure bone density of the whole body and of body sites that are most susceptible to fractures including the hip and spine rather than the heel that is more commonly measured in screenings and health fairs.

On the day of your appointment, please come to Room Wallace 229 Wallace Hall. The day of the scans you should wear loose clothing **with no metal such as zippers**. **Items with metal such as jewelry can be removed when you arrive. You may want to bring a sweatshirt and pants or leggings.**

Guidelines for 1-RM Testing

1. Instruct subject to warm up with light resistance that allows 10 reps.

2. Allow 1 min rest period.

3. Estimate warm up load that will allow subject to complete 3-5 reps.

    - 10-20 lbs added for upper body
    - 30-40 lbs added for lower body

4. Allow 2 min rest period.

5. Estimate conservative, near maximum load, that will allow subject to complete 2-3 reps.

    - 10-20 lbs added for upper body
    - 30-40 lbs added for lower body

6. Allow 2 min rest period.

7. Increase load so subject will attempt 1-RM

    - 10-20 lbs added for upper body
    - 30-40 lbs added for lower body

8. If subject can complete successfully, allow 2 min rest period and repeat step 7.

9. If subject cannot complete successfully, allow 2 min rest period and decrease load until 1-RM is achieved.

    - 5-10 lbs decrease for upper body
    - 15-20 lbs decrease for lower body

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Vita

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