ABSTRACT

EFFECTS OF WEIGHT TRAINING AND A WHEY BEVERAGE ON MUSCULAR HYPERTROPHY AND STRENGTH IN TRAINED MALES

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Background: Ingestion of protein beverages post resistance exercise have been shown to increase muscle mass and strength.

Purpose: The purpose of this investigation was to compare whey protein to whey/carbohydrate supplementation during eight week concentric/eccentric resistance training to determine if one beverage was superior in promoting muscular strength and hypertrophy than the other.

Methods: Twenty resistance-trained males participated in this study and were randomly assigned to either a whey protein or whey/carbohydrate beverage following an 8-week concentric/eccentric resistance training protocol. Seventeen subjects completed all testing and were included in the statistical analysis. Muscle strength was assessed by a one-rep maximum on the bench press and leg press, and isometric knee flexion and extension assessed using the Humac Dynamometer. Anthropometric circumference measurements and body composition were also taken. All measurements were collected at baseline, midpoint, and upon completion of the study.

Results: Both supplemental groups experienced significant increases in muscle strength for 1RM for bench and leg press ($p \leq 0.001$), and knee extension ($p \leq 0.002$), muscular hypertrophy ($p \leq 0.02$), and lean body mass ($p \leq 0.02$).

Conclusion: There was a significant increase in muscle strength, hypertrophy, and lean body mass following the eight-week concentric/eccentric resistance training study for both supplement groups. Therefore, a resistance training program is effective increasing muscle mass and strength regardless of supplementation.

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EFFECTS OF WEIGHT TRAINING AND A WHEY BEVERAGE ON MUSCULAR HYPERTROPHY AND STRENGTH IN TRAINED MALES

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INTRODUCTION

Resistance training has an ability to induce skeletal muscle hypertrophy (Devkota & Layman, 2010; Schoenfeld, 2010, 2013). Resistance training induces muscle damage that requires exogenous dietary protein to repair the damaged tissue in order to grow (Devkota & Layman, 2010; Lemon, 1998; Schoenfeld, 2013). Repeatedly stressing muscle contraction, through weight training, causes the muscle to adapt by hypertrophying in order to prevent future damage (Schoenfeld, 2013).

Adapting to a stimulus such as weight lifting through hypertrophy is caused by the growth of more contractile units/proteins and or larger contractile units/proteins to handle the load being placed on the muscle (Kenney, Wilmore & Costill, 2012). Consuming exogenous protein immediately post resistance training drastically increases recovery time by aiding in the reconstruction of damaged tissue (Ivy & Ferguson, 2010). Furthermore, combining whey protein and carbohydrates seems to encourage even greater recovery than protein only because of the greater insulin response associated with carbohydrate ingestion thus reducing the catabolic effects of resistance training (Ivy & Ferguson, 2010; Kreider, 1999).

Resistance training produces muscle hypertrophy and strength gains through three mechanisms: mechanical tension, muscle damage and metabolic stress (Schoenfeld, 2010). Mechanical tension refers to training load and there appears to be a minimum intensity threshold that must be reached in order to stimulate muscle fiber hypertrophy (Schoenfeld, 2013). The issue with low load intensities seems to be the recruitment of sufficient number of motor neurons

(Schoenfeld, 2013). However low load training (30% of 1RM) to volitional fatigue is capable of inducing nearly identical protein synthesis rates as high intensity loads (90% of 1RM) as well as maintaining elevated levels of protein synthesis at 24 hours (Burd, Mitchell, Churchward-Venne & Phillips, 2012).

Protein synthesis is the construction of new proteins, such as contractile proteins, and is necessary for skeletal muscle hypertrophy (Ivy & Ferguson, 2010). Training to volitional fatigue induces high amounts of metabolic stress, which is a key component to stimulating muscle growth according to Schoenfeld (2010). There are two different kinds of muscle contractions the lowering phase or eccentric contraction and the lifting phase or the concentric contraction (Kenney et al., 2012). Thus the eccentric portion of the lift emphasizes the stretch of the muscle while the concentric part focuses more on force generation to lift the weight. One of Schoenfeld's (2010) criteria for inducing muscle growth is mechanical tension, which is the combination force generated by the muscle and the stretch placed on the muscle (Schoenfeld, 2010).

The timing of protein ingestion is extremely important, supplementing with protein pre-workout and post-workout yields substantial effects on strength and hypertrophic potential when compared to supplementing with protein at other times of the day (Cribb & Hayes, 2006; Esmark, Anderson, Olsen, Richter, Mizuno & Kjaer, 2001).

Supplemental whey protein is well documented in its innate ability to assist in skeletal muscle hypertrophy by increasing protein synthesis following resistance training (Ivy & Ferguson, 2010; Kreider, 1999; & Lemon, 1998).

There are two methods used to rank proteins on their quality, biological value (BV) and protein digestibility corrected amino acid score (PDCAAS). BV represents how effective ingested protein leads to protein synthesis in muscle tissues once the protein is absorbed; there is a maximum BV score of 100 (Stark, Lukaszuk, Prawitz & Salacinski, 2012). The PDCAAS grades sources of proteins on the completeness of their essential amino acid profile, a maximum PDCAAS score is 1.0 and represents that a protein source has every essential amino acid (Stark et al., 2012). Whey protein has one of the highest biological values with a score of 104, whey protein also boasts a 1.0 score on the protein digestibility corrected amino acid score (Stark et al., 2012). These two scores are representative of whey's rapid digestion and its ability to induce protein synthesis (Stark et al., 2012). Hydrolyzed whey protein is supposedly more bioavailable than even whey protein because of the hydrolysis it undergoes (Morifuji, Ishizaka, Baba, Fukuda, Matsumoto, Koga, & Higuchi, 2010). Research on the bioavailability of amino acids showed that hydrolyzed whey had greater and faster increases in plasma amino acid concentrations comparted to non-hydrolyzed whey protein (Morifuji et al., 2010). Thus hydrolyzed whey protein may provide a faster supply of amino acids to the muscle resulting in a quicker elevation in protein synthesis and thus recovery (Morifuji et al., 2010). Muscle hypertrophy is only capable in the presence of a positive protein balance, this is known as protein synthesis (Ivy & Ferguson, 2010). Therefore, whey protein is a perfect candidate to help reach the elevated protein intake needed for individuals engaged in strength training due to exercise induced muscle damage (Lemon, 1998). There is a lack of research on hydrolyzed whey protein because it is a newer form of supplement and thus this study aims to compare the effects of a hydrolyzed whey and carbohydrate plus hydrolyzed whey combined with resistance training.

Purpose

The purpose of this investigation was to compare the effects of whey protein supplementation to whey/carbohydrate supplementation during eight week concentric/eccentric resistance training on changes in muscular strength and hypertrophy.

Hypotheses

1. It was hypothesized that participants receiving the whey/carbohydrate supplement would exhibit greater changes in muscular strength compared to those in the whey only group after eight weeks.
2. It was hypothesized that participants receiving the whey/carbohydrate supplement would show greater increases in muscle cross-sectional area compared to the subjects in the whey only group after eight weeks.

METHODOLOGY

Procedures

This study used a randomized group experimental design. Participants received a specifically formulated whey/carbohydrate beverage (n=8) immediately following weight training or whey protein (n=9) during the eight-week study. See Appendix A for a flow chart of the protocol. Participants concentric/eccentric lifted (n=17), weight training in which the full range of motion is achieved a concentric contraction or lifting phase followed by an eccentric contraction or lowering phase. Anthropometric data, height, weight, body mass index, fat mass and lean mass were recorded in light exercise clothing and bare feet using a wall mounted stadiometer (Birmingham, Great Britain) and calibrated digital scale (InBody 520, Biospace Inc, Los Angeles, CA). Weight, fat mass, percent fat and lean mass, as well as body mass index were assessed using InBody 520. Participants were urged to be well hydrated prior to body composition assessment with the InBody 520. If subjects were not properly hydrated the individual had to redo the test the following day.

The resistance training intervention (Appendix B) was done three times per week for the first four weeks and then four times per week for the final four weeks. The participants were trained either in Gabel hall or in the FIT room of Anderson hall. The participants were all trained using an concentric/eccentric manner in which the weight is lowered (eccentric) and then lifted (concentric) for all sets, repetitions and exercises throughout the duration of the intervention. The rest interval between sets was kept constant for the duration of the protocol at 45-90 seconds.

Participants were urged to keep the time of day they train consistent throughout the program. During training sessions three specifically selected Kinesiology undergraduates and the researcher monitored all participants to assist with spotting and ensure proper form was being used for all exercises. There was no more than eight participants exercising at the same time to allow maximum focus on each individual.

The workout regimen was designed to increase volume (number of sets) while intensity (weight) stays the same while the following week volume lowers and the intensity increases, this cycle was repeated throughout the program. During week one participants used a calculated weight based on their 1RM values to complete three sets of 12 repetitions for each exercise, the following week the weight remained the same but four sets of 12 were completed. The third week the sets dropped back down to three and the repetitions were lowered to 10, the weight was recalculated based on their 1RM values and increased for each exercise, the fourth week the weight remained the same as the 3rd week but participants were asked to complete four sets of 10. Each participant's weight per set and number of repetitions per set were recorded on a data sheet (Appendix C) to track progress.

Muscular strength and hypertrophy assessments (Appendix D) were taken pre-intervention, midway, and post-intervention. The pretesting served as a template to gauge how much weight each participant needed for the training protocol as well as comparison data for the post test. The midway testing served to determine if adjustments needed to be made in the intensity at which the participants were training. Testing procedures for strength and hypertrophy are outlined below.

Participants

Twenty healthy men aged 18-30 years with more than one-year weight lifting experience were recruited to participate in this study. Participants provided signed consent to participate (Appendix E) and filled out medical history forms (Appendix F). Northern Illinois University Institution Review Board approved all study procedures prior to the start of data collection. A questionnaire was filled out by applicants to determine weight training experience within the last year(Appendix F). Participants were recruited using informational flyers (Appendix G) posted on the university campus and fitness centers within a 20-mile radius of campus. Exclusion criteria included use of anabolic androgenic substances (AAS) within the past year and use of performance enhancing supplements within the last six weeks prior to the start of the study. Additional exclusion criteria included food allergies or intolerances to whey protein and/or gluten, as well as sickle cell anemia and implanted electrical devices.

The supplement the participants consumed: whey only (Dymatize) group consumed 28 grams of supplement comprised of 25 grams of whey protein, whey/carbohydrate (Vitargo Post) group consumed 132.5 grams of supplement consisting of 88 grams of carbohydrate and 25 grams of protein. Each subject consumed the appropriate drink following every workout session which resulted in a total of 28 supplement shakes consumed throughout the study.

Muscle Hypertrophy Assessment

Muscle fiber hypertrophy was assessed at the start and the end of the protocol. Muscular hypertrophy was measured using a 60-inch cloth tape. For each participant, the following body measurements were monitored: non-dominate upper arm, chest, waist, hips, and non-dominant thigh. For the upper arm measurement the midpoint between the elbow joint and the glenohumeral joint and for the thigh measurement midpoint between the acetabulofemoral (hip) joint and the tibiofemoral/patellofemoral (knee) joint. For the chest, the appropriate placement was level with the areolas following a longitudinal line around the body. Abdominal circumference was measured with a cloth tape anteriorly halfway between the lowest portion of the ribcage and the iliac crest. Finally, the hips were measured two inches below the iliac crest of the hips. This is the protrusion of the hips in the frontal plane of the body (Baechle, 2008). Body measurements were taken three times and the average value recorded and measured to the nearest 1/16th of an inch. Body measurements were completed prior to the strength assessments The measurements were pulled snuggly on the muscle belly but not too much so that it made an indentation on the skin. All measurements were taken while wearing light exercise clothing.

Strength Assessment

Strength assessments occurred at the start, the half-way point, and at the end of the 8-weeks. Each participant had lower body strength assessed using the Humac dynamometer machine. The maximal strength assessments were performed on CSMi's Humac (Norm Testing and Rehabilitation System Computer Sports Medicine, Inc. Stoughton, MA) for the knee joint. The machine was calibrated according to CSMi's user manual before each day of testing. The participants sat with the back angle of the chair set at 90 degrees during the isometric knee extension and flexion strength assessment of the non-dominant leg. For the isomeric knee flexors and extensors, the participants was secured with adjustable belts across the chest, shoulders, and hips. The alignment of the lateral epicondyle of the knee to the axis of rotation was done visually along with the ankle cuff placement superior to the lateral malleolus and checked by hand with a goniometer. The maximal isometric knee extension and flexion strength assessment were performed three times each at a 45 degree angle and held for five seconds to measure maximal force of the extensors and flexors. Peak torque and average torque in Nm were measured. Participants were given fifteen seconds of rest between each trial. A warm-up set of one isometric contraction, at an angle of 45 degrees, was completed for five seconds before both the flexion and extension exercises. All muscle strength testing was performed in the Neuromuscular Lab in 132 Anderson Hall. The protocol for the Humac is commonly cited throughout the literature. The order of testing flexion and extension peak and average torque for each segment was randomized.

Each participant in this study performed a one repetition maximum (1RM) strength test to assess upper body strength using the bench press exercise and the leg press to assess lower body strength. A 1RM is the maximum amount of weight that a given muscle can move through a complete contraction (eccentric and concentric) one time, with proper form. The only equipment needed for the strength assessment was the bench press with an Olympic bar and a leg press machine with the standard weight plates ranging from two and a half pounds to 45 pounds. These strength measurements were recorded to the nearest five pounds without the assistance of a spotter. For the bench press, the participant needed to be able to lower the bar down to the areolas, pause for a half second, and then press the bar until lockout of the elbows. For the leg press, the participants needed to lower the apparatus so that the knee was just past a 90 degree angle, pause for a half second, then press the platform until the knees lockout. The National Strength and Conditioning Association (NSCA) guidelines were used for all 1RM testing. NSCA guidelines use a proper warm up consisting 3 to 4 sets with 5-10% weight increase each set for upper body and 10-20% for lower body until near the participants 1RM. Once close to the individuals maximum, subsequent weight changes depended on success or failure of the lift, 2.5-5% for upper body and 5-10% for lower body until a 1RM was achieved (Baechle, 2008).

Diet Analysis

Diet Analysis was performed using a three-day food log (Appendix H) that the participants completed at the beginning and middle of the study. They were taught how to approximate serving sizes along with the identification of what was in their food so that the most accurate calorie estimations occurred. It was explained that the more accurate their log, the more accurate the diet results. For example, each participants dietary analysis was broken down into necessary kilocalories per kilogram, percent protein, percent carbohydrates, and percent fats. Dietary logs were analyzed at the start and half-way point of the study to ensure that the participants maintained a similar diet throughout the duration of the procedure. Diets were analyzed to the nearest total calorie and half of a gram of protein.

Statistical Analysis

Between group and within group differences for strength, muscle hypertrophy, and body composition measurements were analyzed using a mixed factor 2 x 3 (supplement group by time) analysis of variance (ANOVA) where time was the within groups factor. The follow-up analyses to significant time main effects were paired t-tests with a Bonferroni adjustment to the level of significance. Significant interactions were followed-up with simple main effects analysis on the time factor. Statistical significance for all data analysis was accepted at the $p<0.05$ level of confidence. Data was analyzed using Statistical Package for Social Sciences for Windows (version 22.0, 2013, SPSS Inc, Chicago, IL).

RESULTS

Twenty male participants were recruited to partake in this research and were randomly divided into a whey protein only or whey protein and carbohydrate supplement. A total of three participants withdrew from the study. One participant in the whey protein group dropped out of the study after 4 weeks with no stated reason and, one participant in the whey and carbohydrate group due to family complications. Additionally, one participant was excluded from the final analysis because his body composition and anthropometric data were flagged as outliers due to an android configuration. Thus, he was viewed as not belonging to the same population as the other participants. A total of 17 participants with (mean ± standard deviation) age (22.11 ± 2.45 years) and height (69.12 ± 2.78 inches) completed the study's requirements and were used in analysis: whey protein (n=9) and whey/carbohydrate (n=8). The participants were instructed prior to the study to keep dietary intake as consistent as possible to minimize the external stimuli effect on the measured variables. The analysis for the dependent variables, muscular hypertrophy (anthropometric measurements of chest, upper arm, waist, hip & thigh; body composition via bioelectrical impedance analysis) and strength (bench press, leg press & humac dynamometer knee flexion & extension), were conducted using a 2x3 mixed factor repeated measures ANOVA.

Body composition data included total body weight, lean body mass and body fat percentage. There was an interaction between time and supplement [$F(1.58, 23.67) = 8.13$, $p = 0.004$] for body weight. There was no significant time effect for whey group [$F(1.47, 11.74) = 1.14$, $p = 0.33$] but there was a significant effect for whey/carbohydrate group [$F(2,14) = 16.63$, $p < 0.0001$]. Weight significantly increased from baseline to post for the whey/carbohydrate group ($p = 0.002$). For lean body mass there was no interaction between time and supplement [$F(1.57, 23.57) = 1.59$, $p = 0.227$] nor a significant difference between supplemental groups ($p = 0.900$). However, lean body mass showed a significant time main effect [$F(1.57, 23.57) = 9.08$, $p = 0.002$) Lean body mass was significantly less at baseline than at the midpoint and final assessments ($p = 0.02$) but the midpoint and final lean body mass did not differ. Body fat percentage was the final body composition analysis and yielded no interaction between time and supplement [$F(2, 30) = 2.66$, $p = 0.086$], and no difference between supplements ($p = 0.096$). Body fat analysis also produced no significant time main effect [$F(2, 30) = 2.19$, $p = 0.129$]. The body composition data can be viewed in Table 1.0

Table 1.0
Body Composition Analysis for Individual Supplemental Groups and Total

Variable	**Whey Mean ± SD (*n*=9)**	**Carbohydrate/Whey Mean ± SD (*n*=8)**	**Total Mean ± SD (*N*=17)**
Weight (lbs)			
Baseline	165.68 ± 24.51	173.95 ± 24.69	169.57 ± 24.19*†′
Midpoint	164.72 ± 24.12	177.00 ± 24.32	170.50 ± 24.28
Post	166.20 ± 22.59	180.30 ± 24.89	172.84 ± 24.06
Lean Mass (lbs)			
Baseline	144.66 ± 18.60	142.11 ± 12.46	143.45 ± 15.58**‡′
Midpoint	145.39 ± 16.55	145.66 ± 12.25	145.52 ± 14.23
Post	147.09 ± 15.33	146.55 ± 13.85	146.84 ± 14.19
Body Fat (%)			
Baseline	12.43 ± 2.47	17.40 ± 9.15	14.77 ± 6.80***‡′
Midpoint	11.38 ± 3.41	16.83 ± 8.80	13.94 ± 6.89
Post	11.16 ± 4.03	17.86 ± 9.27	14.31 ± 7.60

* Baseline & Midpoint < Final, p ≤ 0.02
** Baseline < Midpoint & Final, p ≤ 0.02
*** No Time Effect, p > 0.13
† Interaction between Time & Supplement, p < 0.005
‡ No Interaction between Time & Supplement, p ≥ 0.09
′ No Difference between Supplements, p ≥ 0.10

Anthropometric measurements that were collected during this study include chest, upper arm, waist, hip and thigh circumference. There was no significant interaction between time and supplement [$F(2, 30) = 1.00$, $p= 0.378$] of the chest measurements and no significance difference was found between supplemental groups ($p = 0.388$). The chest circumference measurements did show a significant time main effect[$F(2, 30) = 39.39$, $p < 0.001$]. The baseline, midpoint and final measurements all differed significantly from each other ($p \leq 0.02$).

The upper arm circumference demonstrated a similar effect to the chest. There was no interaction between supplement and time [$F(2, 30) = 0.621$, $p = 0.544$] and no significance was found between supplements ($p= 0.207$). However there was a significant time main effect [$F(2, 30) = 28.59$, $p < 0.001$], all of the data points, baseline, midpoint and final differed from one another ($p \leq 0.02$).

The waist measurements had a significant interaction between time and supplement [$F(1.69, 25.39) = 4.53$, $p = 0.026$]. There was no significant time effect for the whey group [$F(1.45, 11.59) = 0.449$, $p = 0.562$] but there was a significant effect for whey/carbohydrate group [$F(2, 14) = 8.108$, $p = 0.005$]. Waist circumference increased from baseline to post for whey/carbohydrate group ($p = 0.011$).

The hip girth had no supplemental interaction of groups by time [$F(1.66, 24.87) = 0.186$, $p = 0.791$]. However, the hip circumference differed significantly between the whey group and whey/carbohydrate group ($p < 0.05$). The hip measurements did not change significantly over time [$F(1.66, 24.87) = 1.26$, $p = 0.296$].

Thigh girth did not have an interaction between supplement and time [$F(1.75, 26.22) = 1.90$, $p = 0.173$], and supplements did not differ significantly ($p = 0.396$). Although the variable was found to change significantly over time [$F(1.75, 26.22) = 11.81$, $p < 0.001$], baseline thigh circumference was significantly less than the final measurement ($p < 0.001$). All of the anthropometric data is summarized in Table 2.0.

Table 2.0
Anthropometric Measurements for Individual Supplemental Groups and Total

Variable	**Whey Mean ± SD (*n*=9)**	**Carbohydrate/Whey Mean ± SD (*n*=8)**	**Total Mean ± SD (*N*=17)**
Chest (in)			
Baseline	37.88 ± 1.79	38.66 ± 2.85	38.25 ± 2.30*†′
Midpoint	38.53 ± 1.73	39.47 ± 2.97	38.97 ± 2.36
Post	39.07 ± 1.39	40.28 ± 2.72	39.64 ± 2.14
Upper Arm (in)			
Baseline	13.97 ± 1.05	14.48 ± 0.78	14.21 ± 0.94*†′
Midpoint	14.25 ± 0.98	14.83 ± 0.85	14.52 ± 0.94
Post	14.39 ± 0.99	15.05 ± 0.82	14.70 ± 0.94
Waist (in)			
Baseline	31.40 ± 2.90	33.41 ± 4.03	32.35 ± 3.51***‡′
Midpoint	31.17 ± 2.81	33.88 ± 4.40	32.44 ± 3.79
Post	31.39 ± 2.71	34.56 ± 4.03	32.88 ± 3.67
Hip (in)			
Baseline	32.69 ± 3.06	35.95 ± 3.93	34.23 ± 3.78**†″
Midpoint	32.64 ± 3.13	36.13 ± 3.67	34.28 ± 3.74
Post	33.06 ± 2.77	36.28 ± 2.74	34.57 ± 3.14
Thigh			
Baseline	21.15 ± 1.31	21.84 ± 0.81	21.48 ± 1.13***†′
Midpoint	21.82 ± 1.34	22.03 ± 1.56	21.92 ± 1.41
Post	21.82 ± 1.15	22.44 ± 1.09	22.11 ± 1.13

* Baseline < Midpoint < Final, p ≤ 0.02
** No Time Effect, p > 0.73
*** Baseline < Final, p < 0.02
† No Interaction between Time & Supplement, p > 0.17
‡ Interaction between Time & Supplement, p < 0.03
′ No Difference between Supplements, p > 0.14
″ Supplements differ, p < 0.05

The participants strength was assessed with field testing, by two lifts in the gym one, the bench press to test upper body strength and two, the leg press to test lower body strength. The supplemental groups did not change differently over time producing no interaction between time and supplement [$F(2, 30) = 1.83$, $p = 0.179$], with no significant difference between supplemental groups ($p = 0.489$). The bench press was found to have a significant time main effect [$F(2, 30) = 46.90$, $p < 0.001$], the baseline bench press was significantly less than the midpoint, and midpoint bench press was significantly less than the final bench press, thus baseline also was significantly lower than final bench press ($p \leq 0.001$).

The leg press had no significant interaction between supplement and time, [$F(2, 30) = 0.531$, $p = 0.593$] and no significant difference between supplements on leg press 1RM strength ($p = 0.07$). There was a significant time main effect, participants increased their 1RM leg press over the eight week period [$F(2, 30) = 60.77$, $p < 0.001$], baseline, midpoint and final leg presses all differed significantly from each other ($p \leq 0.001$). The bench press and leg press data can be seen in Table 3.0.

Table 3.0
Bench Press and Leg Press Strength Changes for Individual Supplemental Groups and Total

Variable	**Whey Mean ± SD (*n*=9)**	**Carbohydrate/Whey Mean ± SD (*n*=8)**	**Total Mean ± SD (*N*=17)**
Bench Press (lbs)			
Baseline	198.89 ± 41.21	210.00 ± 26.73	204.12 ± 34.56$^{*\dagger\prime}$
Midpoint	211.67 ± 39.37	218.75 ± 23.87	215.00 ± 32.21
Post	219.44 ± 40.73	235.63 ± 20.60	227.06 ± 32.93
Leg Press (lbs)			
Baseline	546.11 ± 39.67	577.50 ± 54.45	560.88 ± 48.42$^{*\dagger\prime}$
Midpoint	604.44 ± 43.04	637.50 ± 34.54	620.00 ± 41.68
Post	637.78 ± 48.68	686.25 ± 48.68	660.59 ± 53.32

* Baseline < Midpoint < Final, $p \leq 0.001$
† No Interaction between Time & Supplement, $p \geq 0.18$
$^{\prime}$ No Difference between Supplements, $p \geq 0.21$

Criterion strength for knee flexion and knee extension, average torque, were assessed using the Humac dynamometer. Knee flexion showed no significant interaction between supplement and time [$F(2, 30) = 0.484$, $p = 0.621$], and no difference between supplement groups (p = 0. 155). There was also no significant change time effect [$F(2, 30) = 1.28$, $p = 0.294$]. For knee extension there was, no interaction between time and supplement [$F(2, 30) = 1.70$, $p = 0.205$] and the groups did not differ significantly between supplements ($p = 0.072$). However, there was a significant time main effect [$F(2, 30) = 10.27$, $p < 0.001$]; baseline and midpoint measurements were significantly lower than the final data point ($p \leq 0.002$), but baseline and midpoint did not differ. The effects discussed for strength measurement by the Humac are displayed in Table 4.0.

Table 4.0
Strength Assessment for Knee Flexion/Extension for Individual Supplemental Groups and Total

Variable	**Whey Mean ± SD (*n*=9)**	**Carbohydrate/Whey Mean ± SD (*n*=8)**	**Total Mean ± SD (*N*=17)**
Knee Flexion (Nm)			
Baseline	111.44 ± 19.88	122.38 ± 29.29	116.59 ± 24.59*†′
Midpoint	107.67 ± 20.38	126.00 ± 30.73	116.29 ± 26.64
Post	113.67 ± 16.19	132.75 ± 29.81	122.65 ± 24.82
Knee Extension (Nm)			
Baseline	236.00 ± 39.61	256.88 ± 40.35	245.82 ± 40.15**†′
Midpoint	234.89 ± 43.25	277.88 ± 39.97	255.12 ± 46.08
Post	255.56 ± 48.43	297.13 ± 28.20	275.12 ± 44.47

* No Time Effect, p > 0.29

** Baseline & Midpoint < Final, p ≤ 0.005

† No Interaction between Time & Supplement, p ≥ 0.21

′ No Difference between Supplements, p ≥ 0.13

The final analysis is the relative strength of the participants' bench press and leg press. The relative strength was calculated by taking each participants' bench press and leg press for each testing interval and dividing it by their weight at the corresponding test interval. There was no significant interaction between supplement and time [$F(2, 30) = 1.98$, $p = 0.155$] and there was no difference between supplement groups ($p = 0.935$). However, the relative bench press analysis was found to have a significant time main effect [$F(2, 30) = 26.04$, $p < 0.001$], relative bench press strength differed significantly between all data collection time points ($p \leq 0.003$).

The relative leg press breakdown had similar effects. There was no interaction between supplement and time [$F(2, 30) = 0.576$, $p = 0.568$], likewise there was no significant difference between the supplements ($p = 0.947$). However, there was a significant time main effect [$F(2, 30) = 56.67$, $p < 0.001$], baseline, midpoint and final data points all differed significantly from each other ($p \leq 0.001$), and is shown in Table 5.

Table 5.0
Relative Strength on Bench Press and Leg Press by Individual Supplemental Groups and Total

Variable	**Whey Mean ± SD (*n*=9)**	**Carbohydrate/Whey Mean ± SD (*n*=8)**	**Total Mean ± SD (*N*=17)**
Bench Press Relative (lbs)			
Baseline	1.22 ± 0.27	1.23 ± 0.25	1.22 ± 0.25$^{*\dagger\prime}$
Midpoint	1.30 ± 0.28	1.26 ± 0.24	1.28 ± 0.26
Post	1.33 ± 0.26	1.33 ± 0.25	1.33 ± 0.25
Leg Press Relative (lbs)			
Baseline	3.34 ± 0.35	3.38 ± 0.57	3.36 ± 0.45$^{*\dagger\prime}$
Midpoint	3.72 ± 0.47	3.66 ± 0.54	3.69 ± 0.49
Post	3.88 ± 0.42	3.85 ± 0.48	3.87 ± 0.44

* Baseline < Midpoint < Final, $p \leq 0.003$
† No Interaction between Time & Supplement, $p \geq 0.16$
$^{\prime}$ No Difference between Supplements, $p \geq 0.94$

The calorie and protein consumption remained relatively constant throughout the study for both groups. Both groups fell short on the necessary caloric intake for strength training. However both groups did meet the protein requirements for strength training. The participants dietary intake is summarized in table 6.0.

Table 6.0
Three-Day Dietary Intake Calorie and Protein Averages

Variable	**Whey (*n*=9)**	**Carbohydrate/Whey (*n*=8)**	**Total (*N*=17)**
Baseline			
Calories (kcal/kg)	31.37	30.78	31.11
Protein (g/kg)	1.43	1.30	1.37
Midpoint			
Calories (kcal/kg)	27.94	34.61	30.90
Protein (g/kg)	1.30	1.58	1.42

DISCUSSION

The purpose of this investigation was to compare the effects of whey protein supplementation to whey/carbohydrate supplementation during eight weeks of a traditional resistance (concentric and eccentric contraction) training protocol on strength and muscular hypertrophy. The findings of the current study advocate that the participants in both supplemental groups experienced muscular hypertrophy as well as increases in strength. This suggests that the training program was likely responsible for these changes and not the type of supplementation. Both groups had significant increases ($p \leq 0.001$) in upper body and lower body strength measured on the bench press and leg press. Likewise both supplemental groups experienced significant hypertrophy in the chest, upper arm and thigh ($p \leq 0.02$) as well as a significant increase in lean body mass ($p \leq 0.02$). The findings of the current study concur with other research which also observed increases in muscular strength and hypertrophy in protein supplemental groups when combined with resistance training (Devkota & Layman, 2010; Ivy & Ferguson, 2010; Schoenfeld, 2010, 2013).

It is well documented that resistance training induces muscle damage that requires an elevation in protein intake to repair the damaged tissue (Devkota & Layman, 2010; Kreider, 1999; Lemon, 1998; Schoenfeld, 2010, 2013;). Receiving protein immediately after a resistance training session provides the greatest recovery compared to supplemental protein at other times of day (Ivy & Ferguson, 2010). Additionally, whey protein plus carbohydrates has been found to increase an individual's recovery ability due to the associated insulin response from the carbohydrates consequently reducing the catabolic effects of the resistance training (Ivy & Ferguson, 2010; Kreider, 1999). Thus, using this knowledge the current study examined the effects of resistance training on strength and hypertrophy while supplementing with either a whey protein or a whey/carbohydrate blend.

Schoefeld (2010) stated that there are three major factors that determine muscle hypertrophy and strength. These factors are mechanical tension, the force generated and the stretch of the muscle under the training loads of exercise, muscle damage, the tearing of contractile proteins and connective tissue, and metabolic stress, the accumulation of various metabolites (i.e. lactate) during exercise (Schoenfeld, 2010). During the current study the participants underwent a considerable amount of metabolic stress at the beginning of the training protocol using lower weight with a higher volume (4 sets of 12 repetitions, see Appendix B). The volume of exercises was altered week to week, slowly decreasing metabolic stress and increasing mechanical tension by increasing intensity (4 sets of 6 reps) and elevating the weight the participants were required to use. This range of intensity along with sets and reps has been found to be the most productive for yielding hypertrophy (Abe, Loenneke, Fahs, Rossow, Thiebaud, & Bemben, 2012).

The body composition of the sample participants changed drastically during the eight-week resistance training protocol. The whey group gained about one pound in total body weight from the baseline measurement to the final measurement. The change in body weight may seem minuscule, but if lean mass and body fat are viewed the change becomes more impressive. The participants in the whey only group increased lean mass by approximately two and a half pounds

(144.66 to 147.09) with a one percentage point reduction in body fat (12.43 to 11.16). The whey/carbohydrate group had a six-pound increase in body weight (173.95 to 180.30), comprised of a four and a half pound gain in lean body mass (142.11 to 146.55) with a one half percentage point increase in body fat (17.40 to 17.86). The increase in body weight and lean body mass occurred as a possible result from the muscle damage obtained from the volume and intensity of the training protocol (Appendix B) (Schoenfeld, 2010).

Unfortunately, these differences in lean body mass and body fat between supplement groups by time were not found to be significant ($p \geq 0.09$) (insufficient power to find significant interaction). However, the analysis of all of the participants showed that body weight and lean body mass changed significantly from the baseline measurement to post measurements ($p \leq 0.02$). The increase in lean body mass as found in the current study is consistent with other post resistance training supplementation studies, which also described increases in lean body mass (Cribb & Hayes, 2006; Esmark et al., 2001).

The anthropometric measurements showed some variation over the course of the eight weeks. The chest measurements for whey increased by one and a fifth inches while the whey/carbohydrate had an increase of one and three quarter inches, this difference between supplements by time was not found to be significant ($p > 0.17$). However, chest girth did illustrate a significant increase over time for all of the participants ($p \leq 0.02$) with a mean increase of just over one and half inches. The potential mechanism behind the increased chest thickness could be the chronic imposed demands of resistance training, which would elicit a hypertrophic response in the area of stimulus (Schoenfeld, 2013).

The upper arm produced a change of just under a half inch for the whey group, while the whey/carbohydrate group had slightly over a half inch increase in upper arm girth, these differences in supplements by time were again not significant ($p > 0.17$). However, the combined participant analysis showed that there was a significant change over time from the start of the training to post training measurements ($p \leq 0.02$). Upper arm hypertrophy is likely the result of a combination of isolated bicep and tricep exercises (curls and extensions) as used in the present study along with the variety of pressing and pulling exercises (bench press and lat pulldown) that were complementary in the hypertrophic response (McCall, Byrnes, Dickinson, Pattany, & Fleck, 1996). The upper arm hypertrophy seen in the current study are much less drastic but still consistent with another study which also observed upper arm grown, using college-aged males and a twelve week training program which resulted in a 14.6% increase in the cross-sectional area of the arm (McCall et al., 1996).

The waist circumference measurements exhibited a slightly different effect than the other anthropometric variables discussed thus far. The whey group showed no distinct change in waist circumference (31.40 ± 2.90 to 31.39 ± 2.71) from baseline testing to post measurements. Whereas the whey/carbohydrate group did display changes in waist girth (33.41 ± 4.03 to 34.56 ± 4.03). Waist circumference responded differently for each supplement group over the course of training; therefore, waist circumference did exemplify a significant time by supplement interaction ($p = 0.03$). The combined results for all of the participants demonstrated little variation in baseline and post measurements (32.35 ± 3.51 to 32.88 ± 3.67); however, this was enough to produce a significant time effect ($p = 0.02$). The waist muscles such as the abdominals, erector spinae (spinal stabilization) and external obliques experience hypertrophy as other muscles of the body specifically due to a heavy stabilization stimulus that is demonstrated during squats (Abe, Kojima, Kearns, Yohena, & Fukuda, 2003). Squats were included in this studies training protocol on a fairly regular basis and as such may explain the increase in waist circumference.

The hip was the only variable to have a significant difference between supplements ($p = 0.048$). However, when viewing the raw data it becomes obvious as to why this variable exhibited a significant difference between supplements. The whey and whey/carbohydrate groups had baseline values of 32.69 ± 3.06 and 35.95 ± 3.93 and post measurements of 33.06 ± 2.77 and 36.28 ± 2.74, respectively. As can be seen from the data neither group showed a significant time effect or a significant time by supplement interaction ($p = 0.80$). However, the two groups had baseline values that were considerably different (32.69 vs 35.95) and post values that were just as separated (33.06 vs 36.28), therefore the magnitude of difference in the initial measurements most likely caused the significance between variables. Since the hip was measured two inches below the iliac crest, the measurement did not incorporate much of the gluteal musculature. The gluteal muscles are a major agonist muscle group in the leg press and squat (De Silva, Brentano, Cadore, Almeida & Kruel, 2008), both of which were used frequently in this study. Therefore, glute hypertrophy likely occurred during this research but based on the anatomical location of the hip measurement this effect was not recorded and therefore, no change in hip girth was seen.

Thigh girth measurements for both groups was similar, whey had just over half an inch increase (21.15 to 21.82) and the whey/carbohydrate group elicited similar hypertrophy of just over half an inch (21.84 to 22.44). There was a variety of leg exercises performed by the athletes, including squats, leg press, Romanian deadlifts, lunges etc, all of which were progressively overloaded with mechanical tension and metabolic stress based on the resistance training protocol (Appendix B). A chronic overload stress placed on a muscle group will stimulate adaptation through hypertrophy and may explain the changes in leg girth experienced by all the participants ($p < 0.001$) (Schoenfeld, 2013).

Muscle hypertrophy is largely based on the consumption of enough calories and protein to sustain heavy resistance training as well as promote the creation of additional muscle tissue to prevent future damage (Hoffman, Ratamess, Tranchina, Rashti, Kang, & Faigenbaum, 2009; Ivy & Ferguson, 2010). Strength trained individuals have much higher protein and caloric needs to aid recovery from tissue damage sustained from resistance exercise (Hoffman et al., 2009; Lemon, 1998). It is recommended that strength trained individuals consume 44-50 kcal/kg including 1.2-1.7 g/kg protein to adequately recover from heavy exercise and to promote muscular growth (Hoffman et al., 2009; Lemon, 1998). Both the whey group and the whey/carbohydrate fell short of the necessary caloric intake, 44-50 kcal/kg at both collection points, however both groups consumed adequate protein between 1.2 and 1.7 g/kg at each collection point. Thus based on the participants caloric consumption they may not have maximized the hypertrophic potential even with adequate protein intake.

Protein synthesis is also another requirement for skeletal muscle hypertrophy (Ivy & Ferguson, 2010). The use of hydrolyzed whey protein in both the whey only and whey carbohydrate group should have sped up the delivery of amino acids to the muscle allowing for accelerated recovery from the training demands (Morifuji, Ishizaka, Baba, Fukuda, Matsumoto, Koga, & Higuchi, 2010). Hydrolyzed whey protein is also capable of stimulating a substantial insulin response without the need of carbohydrates allowing faster absorption of amino acids by the muscle (Mollica, 2012). However, the ingestion of hydrolyzed whey plus a glucose solution has shown to induce a two to four times greater insulin response than the consumption of beverages such as milk suggesting a greater potential for accelerated recovery from heavy resistance training (Calbet & MacLean, 2002). Furthermore, the leucine content in the supplements would have provided additional stimuli for muscle protein synthesis. Leucine is an amino acid that is directly linked to muscle protein synthesis (Devkota & Layman, 2010). Both the whey protein and whey/carbohydrate supplement contained 2.7 grams of leucine, however it is recommended that at least 3 grams of leucine is consumed post workout to maximize protein synthesis (Stark, Lukaszuk, Prawitz & Salacinski, 2012).

Strength is a variable that is relentlessly pursued by those who actively train with weights, and as such it plays a pivotal role in this research. The bench press is considered the ultimate test of upper body strength utilizing a great majority of the musculature in the upper body (Cribb & Hayes, 2006). Collapsed across both supplement groups there was a significant increase in bench press strength; baseline, midpoint and final bench press all differed from each other ($p \leq 0.001$). However, there was no interaction between the supplement and time, this means that both groups had similar increases at each data collection point, but the magnitude of these changes may be different. The whey group had a mean baseline bench press of 198.89 lbs and a final mean bench press of 219.44 lbs, this is an average increase of 10.3%. The whey/carbohydrate had a mean baseline bench press of 210.00 lbs and a final mean bench press of 235.63 lbs, this is an average increase of 12.2%. While the interaction was not found to be statistically significant ($p \geq 0.18$) this can be considered practical significance for the sample of participants, the whey/carbohydrate group increased their mean bench press by an average of five pounds more than the whey group. A 2 percentage point difference in bench press strength after eight weeks of training could develop into an even greater difference after a longer training cycle. The increase in bench press strength is likely contributable to the various chest exercises used in the training protocol (Appendix B). The participants were required to perform a variety of pressing exercises that involve the chest, deltoids and triceps, all of which play a role in bench press strength (Baechle, 2008).

Additionally the increases in strength could be contributed to the hypertrophy experienced. Hypertrophy is an increase in the contractile units of muscle tissue, where more contractile units result in a higher tension production (Kenney et al., 2012). The increased strength measurements in the current study are consistent with multiple other studies increases in 1RM strength post resistance training intervention (Farthing & Chilibeck, 2003; Gillies et al., 2006; McCall et al., 1996). Additional researchers have concluded whey protein supplementation immediately post a resistance training protocol result in drastic increases in 1RM, whereas other times of day supplementation, or no supplementation at all did not see these elevated 1RM's (Cribb & Hayes, 2006; Esmark et al., 2001).

Leg Press was used as the lower body strength test, it is much safer than the squat and it stimulates the use of nearly all the same muscles (Baechle, 2008). The leg press did see a significant increase for all participants across time ($p \leq 0.001$). However, there was not a statistical significance ($p \geq 0.18$) for the interaction between supplement and time but there may have been practical significance. The whey participants increased their mean leg press from a baseline of 546.11 lbs to a final reading of 637.78 lbs, an average improvement of approximately

90 lbs or 16.8%. The whey/carbohydrate group increased their mean leg press from baseline, 577.50 lbs to a final assessment of 686.25 lbs, an average improvement of approximately 108 lbs or 18.8%. Again the interaction was not found to be statistically significant ($p \geq 0.18$), however there is a fair amount of practical significance for this sample of participants. Adding an additional 18 pounds or 2 percentage points on an individual's 1RM leg press strength in only eight weeks is a considerable achievement in a short time frame and may turn into even greater alterations with a longer training intervention. Leg press strength was likely augmented by the use of compound lower body exercises such as the squat and Romanian deadlifts. Furthermore, as stated above the increase in strength could partly be a result of the larger muscle mass, allowing a greater force production thus increasing 1RM strength (Kenney et al., 2012). The increase in leg press strength again is consistent with the reviewed literature where researchers have also observed increases in 1RM strength (Farthing & Chilibeck, 2003; Gillies et al., 2006; McCall et al., 1996). The increase in strength seems to be exacerbated by supplementation as present in this study, this is also in alliance with others that have indicated an immediate post workout supplementation yields superior results in strength than other times of supplementation or no supplementation (Cribb & Hayes, 2006; Esmark et al., 2001).

The Humac dynamometer is considered a gold standard for testing isolated muscle groups in terms of muscular strength (Tsiros, Grimshaw, Shield, & Buckley, 2011). The Humac was used to isolate the hamstring muscles, knee flexion, and the quadricep muscles, knee extension. The knee flexion analysis of average torque did not show a significant change over time ($p > 0.29$), however, the sample participants' flexion did increase throughout the study. The whey group increased from baseline 111.44 Nm to final 113.67 Nm, a 2% elevation in knee flexion. The whey/carbohydrate group increased their baseline value of 122.38 Nm to a final reading of 132.75 Nm, yielding a 8.5% change in knee flexion. The results of knee flexion were expected because of the lack of isolated hamstring exercises during the training protocol that mimic the movement done on the Humac dynamometer. The hamstrings are one of the prime movers in the leg press which increased for all participants, however this is likely due to the use of muscles such as the hip flexors and gluteal muscles. These muscles are not used during the knee flexion test on the Humac because the Humac completely isolates the hamstring muscle group. Additionally the lack of significance could be more of a function of disparity in the standard deviation between groups. Knee extension however, was found to have a significant time effect ($p \leq 0.001$), but no significant interaction while a practically significant interaction exists for the same. Whey only participants increased the mean baseline value of 236.00 Nm to a mean final value of 255.56 Nm, an 8.3% change in knee extension. The whey/carbohydrate group went from a mean baseline value of 256.88 Nm to a final mean extension of 297.13 Nm, this is a change of 15.7% in extension strength. The increases in knee extension are likely a result of the thigh hypertrophy and increased leg press strength outlined above. The differences in percent increase in strength for the dynamometer are more drastic that the other variables. Practical significance of muscle strength has not be defined throughout literature, but would be considered for this study and the increase found in muscle strength.,

Strength can occur due to two adaptations, neural and hypertrophic (Gabriel, Kamen, & Frost, 2006; Seynnes, De Boer, & Narici, 2007). Initial strength gains occur mainly from neural activation such as motor unit recruitment, motor unit synchronization, and rate coding (Gabriel et al., 2006). Some studies suggest that these neural factors only play a role for four to six weeks and then hypertrophic adaptations are responsible for strength increases (Seynnes et al., 2007). While other studies propose neural factors can be the primary medium for strength elevations for up to eight weeks before muscular hypertrophy would play a role (Gabriel et al., 2006). However, this effect depends on the training status of the athletes. Trained individuals have much more efficient neural drive allowing faster and more forceful muscle contractions, as such trained athletes neural adaptations to a new stimulus only occur for approximately two weeks (Aagaard, Simonsen, Andersen, Magnusson & Dyhre-Poulsen, 2002). During a 21-week resistance training protocol using both trained and untrained athletes, strength increases were observed in both groups after only seven weeks (Ahtiainen, Pakarinen, Alen, Kraemer, & Hakkinen, 2003). In the strength trained athletes the increase in strength after seven weeks was associated with the increased cross-sectional area of the tested muscle, while the untrained individuals also had an increase in strength there was no measurable hypertrophy, thus the authors concluded neural factors were responsible in this group (Ahtiainen et al., 2003). Additional observations have seen hypertrophy in strength trained athletes after only 20 days of resistance training resulting in elevated strength without major changes in neural recruitment (Seynnes et al., 2007). The strength variables in this study, bench press and leg press, both saw a significant time effect ($p \leq 0.001$). In consideration of the research mentioned, the current study used only trained athletes as participants. Thus the increase in strength on the bench press and leg press likely occurred due to hypertrophic adaptations and not neural factors.

There were a few limitations the present study encountered. The first was the limited sample size ($N = 17$), which resulted in insufficient power to find the interaction effect seen for several significant variables. This is a small amount of participants compared to some of the literature reviewed, 60 subjects were used by Higbie et al. (1996), 34 individuals participated in the research done by Farthing and Chilibeck (2003), and 28 participants were used in Gillies et al. (2006) research. Secondly, the availability of machines or exercises to choose from was fairly restricted. The facility where the research was conducted in was extremely well equipped for basic free weight exercise but lacked machines, cable apparatuses and other equipment that most commercial fitness centers possess. A greater variety of machines, cables etc. would have provided a plethora of exercise options to continually introduce new stimuli, which is needed for muscular hypertrophy since the body adapts to a given stimulus at a remarkable rate (Schoenfeld, 2013). Another limitation was the definition used to indicate if an individual was "trained" and thus allowed to participate in the research. The current study required that individuals have at least one year of resistance training immediately prior to beginning the study. However, training styles such as a bodybuilding dominate regimen may elicit a different response than someone who used a powerlifting dominate regimen.

Lastly, was the duration of training protocol, this research was confined to 8-weeks. A longer training protocol of 12-weeks or more may have changed the outcome of both the major variables analyzed, such as muscle strength and hypertrophy in the present study. Neuromuscular adaptations often account for increases in strength during the first eight to nine weeks of resistance training, while hypertrophic adaptations occur at a later stage in the training protocol in untrained participants, trained participants elicit a slightly different response (Brandenburg & Docherty, 2002). Individuals with previous strength training have efficient neural drive allowing faster muscle contraction and elevated force production (Aagaard et al., 2002). This superior neural drive of trained athletes forces them to undergo hypertrophic adaptations to resistance training much sooner than untrained individuals (Aagaard et al., 2002). We tried to account for the shortened time in this study by removing neuromuscular adaptations as a reason for an increase in strength by using trained athletes, but even trained athletes exhibit a certain degree of neural plasticity to new training stimulus (Seynnes et al., 2007; Gabriel et al., 2006). Thus based on the duration of the present studies training protocol some of the strength increases could be due to neural factors. However, the use of trained athletes, as such in this study, should have minimized the contribution of neural adaptations and maximized hypertrophic adaptations as explanation for the increased strength. Different results may be found with using a longer protocol for either trained or untrained individuals.

Thus, there are many directions for future research. First, using a larger sample size than the current study so that the results may be better generalized to the normal population. Using a more strict definition of “trained” would also be a good recommendation for future research. This way all the participants have a similar training background and thus another variable can be held constant. Additional considerations for future research should include training protocol duration; the present study was only conducted for only eight weeks. Therefore, future research should analyze if a longer training cycle will express continued benefits and if the supplements would differ significantly over increased time. Also, it would be interesting to conduct research to determine if different training experiences, such as eccentric only training, would elicit different responses to these supplements.

CONCLUSION

In conclusion, the present study investigated the effects of whey supplementation to whey/carbohydrate supplementation during resistance training on muscular strength and hypertrophy in males. Supplementation type did not have a significant effect on hypertrophy or strength. However, across time both supplemental groups yielded a mean gain of three and a half pounds of lean body mass, an average increase of 23 pounds to the bench press and a mean improvement of 100 pounds on the leg press. Thus, it can be concluded that a resistance training program, regardless of supplementation, is effective at increasing lean body mass and strength.

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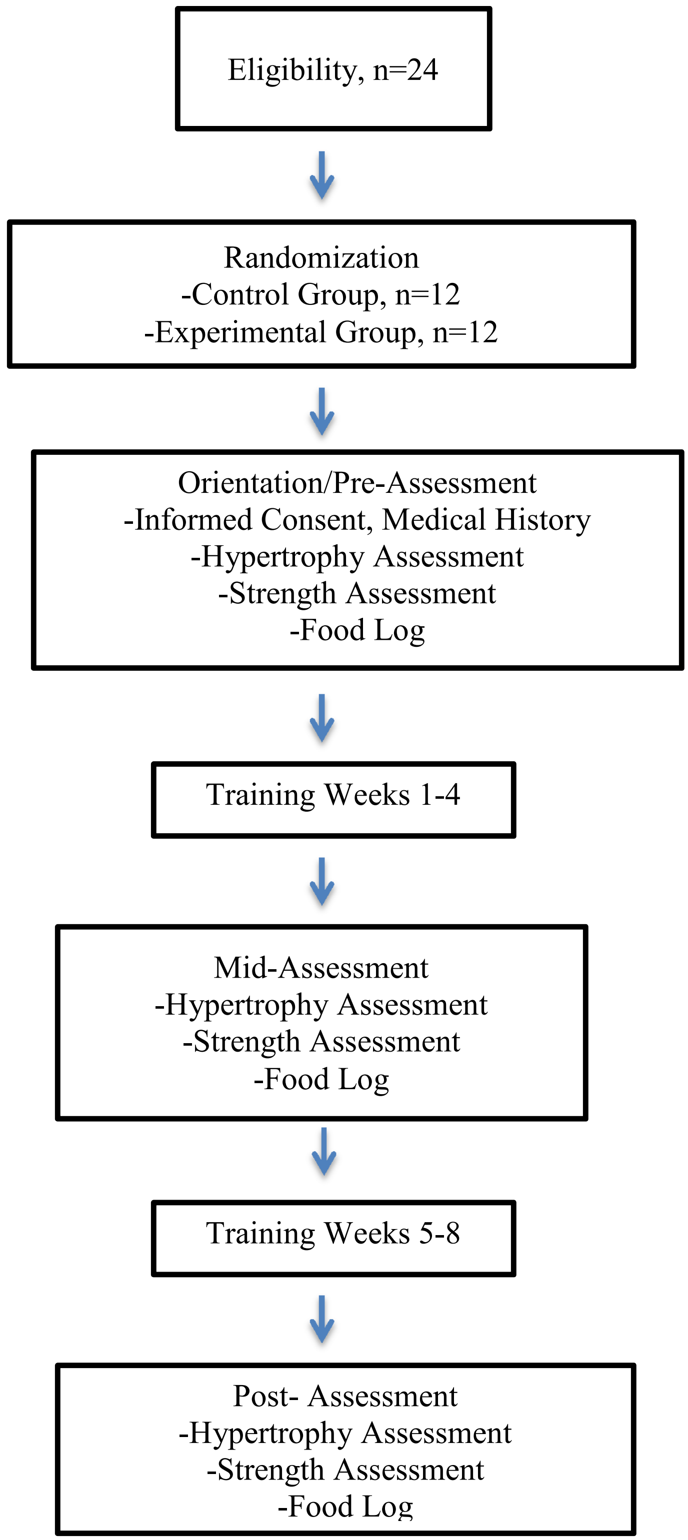
APPENDIX A

FLOW CHART

Flow Chart


Eligibility, n=24
Randomization
-Control Group, n=12
-Experimental Group, n=12
Orientation/Pre-Assessment
-Informed Consent, Medical History
-Hypertrophy Assessment
-Strength Assessment
-Food Log
Training Weeks 1-4
Mid-Assessment
-Hypertrophy Assessment
-Strength Assessment
-Food Log
Training Weeks 5-8
Post- Assessment
-Hypertrophy Assessment
-Strength Assessment
-Food Log

APPENDIX B

EXERCISE PROTOCOL

EXERCISE PROTOCOL

8 Week Resistance Training Program

Lower Body Exercises:

1. Barbell Squats
2. Leg Press
3. Barbell Lunge
4. Leg Extension
5. Leg Curl
6. Romanian Deadlift
7. Barbell Calf Raises
8. Planks
9. Sit-ups

Upper Body Exercises:

1. Barbell Bench Press
2. Incline Barbell Bench Press
3. Dumbbell Chest Fly
4. Barbell Row
5. Lat Pulldown
6. Dumbbell Row
7. Barbell Military Press
8. Dumbbell Military Press
9. Dumbbell Lateral Raise
10. Barbell Curl
11. Dumbbell Curl
12. Tricep Cable Extension
13. Barbell Tricep Extensions

Week 1

Monday, Day 1

1. Barbell Squat (3x12)

2. Barbell Bench Press (3x12)
3. Barbell Row (3x12)
4. Barbell Military Press (3x12)
5. Barbell Curl (3x12)
6. Barbell Tricep Extension (3x12)
7. Planks

Wednesday, Day 2

1. Leg Press (3x12)
2. Incline Barbell Bench Press (3x12)
3. Lat Pulldowns (3x12)
4. Dumbbell Military Press (3x12)
5. Dumbbell Curl (3x12)
6. Tricep Cable Extensions (3x12)
7. Sit-ups

Friday, Day 3

1. Barbell Squat (3x12)
2. Barbell Bench Press (3x12)
3. Barbell Row (3x12)
4. Barbell Military Press (3x12)
5. Barbell Curl (3x12)
6. Barbell Tricep Extension (3x12)
7. Planks

Week 2

Monday, Day 4

1. Leg Press (4x12)
2. Incline Barbell Bench Press (4x12)
3. Lat Pulldowns (4x12)
4. Dumbbell Military Press (4x12)
5. Dumbbell Curl (4x12)
6. Tricep Cable Extensions (4x12)
7. Sit-ups

Wednesday, Day 5

1. Barbell Squat (4x12)
2. Barbell Bench Press (4x12)

3. Barbell Row (4x12)
4. Barbell Military Press (4x12)
5. Barbell Curl (4x12)
6. Barbell Tricep Extension (4x12)
7. Planks

Friday, Day 6

1. Leg Press (4x12)
2. Incline Barbell Bench Press (4x12)
3. Lat Pulldowns (4x12)
4. Dumbbell Military Press (4x12)
5. Dumbbell Curl (4x12)
6. Tricep Cable Extensions (4x12)
7. Sit-ups

Week 3

Monday, Day 7

1. Barbell Squat (3x10)
2. Barbell Bench Press (3x10)
3. Barbell Row (3x10)
4. Barbell Military Press (3x10)
5. Barbell Curl (3x10)
6. Barbell Tricep Extension (3x10)
7. Planks

Wednesday, Day 8

1. Leg Press (3x10)
2. Incline Barbell Bench Press (3x10)
3. Lat Pulldowns (3x10)
4. Dumbbell Military Press (3x10)
5. Dumbbell Curl (3x10)
6. Tricep Cable Extensions (3x10)
7. Sit-ups

Friday, Day 9

1. Barbell Squat (3x10)
2. Barbell Bench Press (3x10)
3. Barbell Row (3x10)
4. Barbell Military Press (3x10)
5. Barbell Curl (3x10)

6. Barbell Tricep Extension (3x10)
7. Planks

Week 4

Monday, Day 10

1. Leg Press (4x10)
2. Incline Barbell Bench Press (4x10)
3. Lat Pulldowns (4x10)
4. Dumbbell Military Press (4x10)
5. Dumbbell Curl (4x10)
6. Tricep Cable Extensions (4x10)
7. Sit-ups

Wednesday, Day 11

1. Barbell Squat (4x10)
2. Barbell Bench Press (4x10)
3. Barbell Row (4x10)
4. Barbell Military Press (4x10)
5. Barbell Curl (4x10)
6. Barbell Tricep Extension (4x10)
7. Planks

Friday, Day 12

1. Leg Press (4x10)
2. Incline Barbell Bench Press (4x10)
3. Lat Pulldowns (4x10)
4. Dumbbell Military Press (4x10)
5. Dumbbell Curl (4x10)
6. Tricep Cable Extensions (4x10)
7. Sit-ups

Week 5

Monday, Day 13

1. Barbell Squat (3x8)
2. Leg Extension (3x8)
3. Leg Curl (3x8)
4. Barbell Calf Raise (3x8)
5. Barbell Bench Press (3x8)
6. Incline Barbell Bench Press (3x8)
7. Dumbbell Chest Fly (3x8)

8. Tricep Cable Extension (3x8)
9. Barbell Tricep Extension (3x8)

Tuesday, Day 14

1. Barbell Row (3x8)
2. Lat Pulldown (3x8)
3. Dumbbell Row (3x8)
4. Barbell Military Press (3x8)
5. Dumbbell Military Press (3x8)
6. Dumbbell Lateral Raise (3x8)
7. Barbell Curl (3x8)
8. Dumbbell Curl (3x8)

Thursday, Day 15

1. Leg Press (3x8)
2. Barbell Lunge (3x8)
3. Romanian Deadlift (3x8)
4. Barbell Calf Raise (3x8)
5. Barbell Bench Press (3x8)
6. Incline Barbell Bench Press (3x8)
7. Dumbbell Chest Fly (3x8)
8. Tricep Cable Extension (3x8)
9. Barbell Tricep Extension (3x8)

Friday, Day 16

1. Barbell Row (3x8)
2. Lat Pulldown (3x8)
3. Dumbbell Row (3x8)
4. Barbell Military Press (3x8)
5. Dumbbell Military Press (3x8)
6. Dumbbell Lateral Raise (3x8)
7. Barbell Curl (3x8)
8. Dumbbell Curl (3x8)

Week 6

Monday, Day 17

1. Barbell Squat (4x8)
2. Leg Extension (4x8)
3. Leg Curl (4x8)

4. Barbell Calf Raise (4x8)
5. Barbell Bench Press (4x8)
6. Incline Barbell Bench Press (4x8)
7. Dumbbell Chest Fly (4x8)
8. Tricep Cable Extension (4x8)
9. Barbell Tricep Extension (4x8)

Tuesday, Day 18

1. Barbell Row (4x8)
2. Lat Pulldown (4x8)
3. Dumbbell Row (4x8)
4. Barbell Military Press (4x8)
5. Dumbbell Military Press (4x8)
6. Dumbbell Lateral Raise (4x8)
7. Barbell Curl (4x8)
8. Dumbbell Curl (4x8)

Thursday, Day 19

1. Leg Press (4x8)
2. Barbell Lunge (4x8)
3. Romanian Deadlift (4x8)
4. Barbell Calf Raise (4x8)
5. Barbell Bench Press (4x8)
6. Incline Barbell Bench Press (4x8)
7. Dumbbell Chest Fly (4x8)
8. Tricep Cable Extension (4x8)
9. Barbell Tricep Extension (4x8)

Friday, Day 20

1. Barbell Row (4x8)
2. Lat Pulldown (4x8)
3. Dumbbell Row (4x8)
4. Barbell Military Press (4x8)
5. Dumbbell Military Press (4x8)
6. Dumbbell Lateral Raise (4x8)
7. Barbell Curl (4x8)
8. Dumbbell Curl (4x8)

Week 7

Monday, Day 21

1. Barbell Squat (3x6)
2. Leg Extension (3x6)
3. Leg Curl (3x6)
4. Barbell Calf Raise (3x6)
5. Barbell Bench Press (3x6)
6. Incline Barbell Bench Press (3x6)
7. Dumbbell Chest Fly (3x6)
8. Tricep Cable Extension (3x6)
9. Barbell Tricep Extension (3x6)

Tuesday, Day 22

1. Barbell Row (3x6)
2. Lat Pulldown (3x6)
3. Dumbbell Row (3x6)
4. Barbell Military Press (3x6)
5. Dumbbell Military Press (3x6)
6. Dumbbell Lateral Raise (3x6)
7. Barbell Curl (3x6)
8. Dumbbell Curl (3x6)

Thursday, Day 23

1. Leg Press (3x6)
2. Barbell Lunge (3x6)
3. Romanian Deadlift (3x6)
4. Barbell Calf Raise (3x6)
5. Barbell Bench Press (3x6)
6. Incline Barbell Bench Press (3x6)
7. Dumbbell Chest Fly (3x6)
8. Tricep Cable Extension (3x6)
9. Barbell Tricep Extension (3x6)

Friday, Day 24

1. Barbell Row (3x6)
2. Lat Pulldown (3x6)
3. Dumbbell Row (3x6)
4. Barbell Military Press (3x6)
5. Dumbbell Military Press (3x6)

6. Dumbbell Lateral Raise (3x6)
7. Barbell Curl (3x6)
8. Dumbbell Curl (3x6)

Week 8

Monday, Day 25

1. Barbell Squat (4x6)
2. Leg Extension (4x6)
3. Leg Curl (4x6)
4. Barbell Calf Raise (4x6)
5. Barbell Bench Press (4x6)
6. Incline Barbell Bench Press (4x6)
7. Dumbbell Chest Fly (4x6)
8. Tricep Cable Extension (4x6)
9. Barbell Tricep Extension (4x6)

Tuesday, Day 26

1. Barbell Row (4x6)
2. Lat Pulldown (4x6)
3. Dumbbell Row (4x6)
4. Barbell Military Press (4x6)
5. Dumbbell Military Press (4x6)
6. Dumbbell Lateral Raise (4x6)
7. Barbell Curl (4x6)
8. Dumbbell Curl (4x6)

Thursday, Day 27

1. Leg Press (4x6)
2. Barbell Lunge (4x6)
3. Romanian Deadlift (4x6)
4. Barbell Calf Raise (4x6)
5. Barbell Bench Press (4x6)
6. Incline Barbell Bench Press (4x6)
7. Dumbbell Chest Fly (4x6)
8. Tricep Cable Extension (4x6)
9. Barbell Tricep Extension (4x6)

Friday, Day 28

1. Barbell Row (4x6)

2. Lat Pulldown (4x6)
3. Dumbbell Row (4x6)
4. Barbell Military Press (4x6)
5. Dumbbell Military Press (4x6)
6. Dumbbell Lateral Raise (4x6)
7. Barbell Curl (4x6)
8. Dumbbell Curl (4x6)

APPENDIX C

EXERCISE PROTOCOL DATA SHEET

EXERCISE PROTOCOL DATA SHEETS

Data Sheet

Subject:

Date:

Week:

Day:

Time:

Exercise	Set 1 Weight (lbs)/ Reps (#)	Set 2 Weight (lbs)/ Reps (#)	Set 3 Weight (lbs)/ Reps (#)	Set 4 Weight (lbs)/ Reps (#)
	/	/	/	/
	/	/	/	/
	/	/	/	/
	/	/	/	/
	/	/	/	/
	/	/	/	/
	/	/	/	/
	/	/	/	/
	/	/	/	/

APPENDIX D

ANTHROPOMETRIC DATA SHEET

ANTHROPOMETRIC DATA SHEET

Participant_______

Anthropometric Measurements

Measurement	Day 1	Day 28	Day 56
Chest (in)			
Upper Arm (in)			
Waist (in)			
Hips (in)			
Thighs (in)			

Body Composition

Measurement	Day 1	Day 28	Day 56
Body-fat Percent			
Lean Body Mass (lbs)			
Weight (lbs)			

Strength Measurements

Measurement	Day 1	Day 28	Day 56
Bench Press (lbs)			
Leg Press (lbs)			

Humac Dynamometer Measurements

Measurement	Day 1	Day 28	Day 56
Knee Flexion			
Knee Extension			

APPENDIX E

INFORMED CONSENT FORM

Consent to Participate in the Supplement Weight Training Study

You have been invited to participate in a research project designed to test the effect of whey protein supplementation post resistance training on muscular strength, muscular growth and body composition alterations. This study is being conducted by Anthony Nielsen, a graduate student in Nutrition and at Northern Illinois University.

If you meet the exclusion criteria of this study, you will be asked to complete an eight week resistance weight training program. On days 1, 28 and 56 of the study your muscular strength will be assessed by a Humac machine and having you a 1RM on bench press and leg press, muscle size will be assessed using a tape measure (arm, chest, waist, hips, and thigh) and body composition assessed using a special scale called InBody 520. The measurements will take 30-45 minutes to complete. On day 28 of the study you will need to have your strength reassessed and your workout routine adjusted accordingly to allow for further strength and hypertrophy gains. The session will take approximately 20 minutes to complete.

I understand that participation in this study will involve three-to-four one hour weight lifting sessions per week for the duration of the eight-week study at a designated area. The weight lifting sessions will be individualized for you based on your day 1 strength information. On day 28 of the study your strength will be reassessed and your weight lifting routine modified accordingly to maximize strength gains. I understand that I will be expected to drink the whey protein/carbohydrate or whey protein beverage before leaving the training session.

I am aware that my participation is voluntary and I may withdraw at any time without penalty or prejudice, and that if I have any additional questions concerning this study, I may contact Anthony Nielsen at (815) 718-1765 or his advisor Dr. Amanda Salacinski at (815) 753-5625. I understand that if I wish further information regarding my rights as a research subject, I may contact the Office of Research Compliance at Northern Illinois University at (815) 753-8588.

I understand that the intended benefits of this study include information on the effects of protein and its results on muscle. As the subject you will benefit from an exercise program designed specifically to your current fitness level, as well as receiving dietary analysis and assistance on how to eat for maximum recovery.

I understand that there is the potential risk of muscle discomfort that may result from weightlifting. This discomfort will go away after a few days. Northern Illinois University policy does not provide for compensation for, nor does the University carry insurance to cover injury or illness incurred as a result of participation in University sponsored research projects. Upon suffering a minor injury, subjects will be referred to NIU health services and in the event of serious injury emergency medical services will be notified immediately. Your participation is voluntary and you may withdraw at any time without penalty or prejudice.

I understand that all information gathered during this study will be kept confidential by giving all participants a number that is representative of them, and storing the information in a confidential file cabinet separate from the data, which will be locked when not in use. The eight-week exercise program results information will only be accessible by the researcher and the advisor.

I understand that my signature below is consent to participate in the Supplement Weight Training Study. I understand that my consent to participate does not constitute a waiver of any legal rights or redress I might have as a result of my participation, and I acknowledge that I have received a copy of this form.

Signature_______________________________________ Date___________

APPENDIX F

MEDICAL HISTORY FORM

MEDICAL HISTORY FORM

Name:___________________________ Date of Birth:______________

Age: _________ Sex: M F

Height:_____________ Weight:____________

Emergency Contact Person:_________________________ Phone:__________________

DO YOU NOW OR HAVE YOU EVER HAD:

(Please answer YES or NO and explain any YES answers in the space provided)

PART I: KNOWN DISEASES

Do you currently have:

____ Cardiovascular disease, peripheral vascular disease, and/or cerebrovascular disease?

____ Asthma?

____ Interstitial lung disease?

____ Cystic fibrosis?

____ Chronic Obstructive Pulmonary Disease (COPD)?

____ Diabetes (Type 1 or 2)?

____ Any thyroid disorders?

____ Renal or liver disease?

PART II: SIGNS AND SYMPTOMS

____ Do you experience pain and/or discomfort in the chest, neck, jaw, arms, or other areas during mild exercise?

____ Do you feel short of breath at rest, with typical daily, daily activities, or with mild exercise?

____ Do you feel short of breath while lying down flat?

____ Are you awoken in the middle of night due to feeling short of breath and/or severe coughing/wheezing?

____ Do you often feel dizzy at rest or with mild exercise?

____ Do you suddenly pass out or lose consciousness while at rest or with mild exercise?

____ Have you experienced ankle edema (swollen ankles)?

____ Do you have heart palpitations and/or tachycardia at rest or with mild exercise?

____ Do you suffer from muscle cramping, burning, numbness, or fatigue in your calf muscles at rest or with mild exercise?

____ Do you have a known heart murmur?

____ Do you have unusual fatigue with typical, daily activities?

PART III: CORONARY ARTERY DISEASE RISK FACTORS

____ Are you a male older than 45 years, or a female older than 55 years?

____ Do you have a close blood relative who has had a heart attack or heart surgery before the age or 55 (Dad, brother) or age 65 (Mom, sister)?

____ Do you smoke, or did you just quit smoking within the past 6 months?

____ For the last 3 months, do you get less than 30 minutes of moderate-intense exercise, less than 3 days per week?

____ Are you at least 20lbs overweight?

____ Is your blood pressure over 140/90 mmHg, or are you on blood pressure medication?

____ Is your cholesterol greater than or equal to 200 mg/dL, or are you on cholesterol medication?
____ Is your fasting glucose greater than or equal to 100ml/dL?

PART IV:

Can you think of any other conditions that would be aggravated by maximal-effort exercise?

____

____

Are you taking prescription medications? If so, please list them and for what reasons you are taking them.

____

____

Do you know of **ANY OTHER REASON(S)** for why you shouldn't partake in moderate to high-levels of intense exercise?

____

Are you pregnant? (females) Yes No

PART V: SPECIFIC TO PROTOCOL

____ Do you have musculoskeletal problems that limit what/how you exercise?
____ Have you had a major musculoskeletal injury (broken bones, torn ligaments/tendons, etc.) that has limited your ability to exercise in the past 12 months?
____ Have you ever experienced compartment syndrome (compression of nerves, blood vessels, and muscle tissue inside closed space or a limb)?
____ Have you ever experienced fasciotomy (fascia is cut to relieve tension/pressure due to compartment syndrome)?
____ Do you have sickle cell anemia?
____ Do you have an allergies/intolerances to whey protein, gluten or glutamine?
____ Do you have any implanted electric devices?
____ Do you have at least 1 year of weight lifting / resistance training experience within the past year?

PART VI: PROTOCOL RISKS

Have you recently experienced:

____ Muscle trauma?
____ Muscle tears?
____ Swelling (Edema) of joints (knee, elbow)?
____ Any kind of knee/joint problems?
____ Tendonitis?
____ Cold or flu-like symptoms?
____ Other acute, short-term illness?
____ Soft tissue injury?
____ How many times have you visited the doctor in the last 12 months?
____ How many upper respiratory infections have you had in the past 12 months?
____ How many days of work/class have you missed due to illness in the past 12 months?
____ Can you think of any other condition you have that would be worsened by maximal exercise?

____ Are you aware of any other condition that may impair your ability to fully participate in exercise training, adapt properly to training, or perform fitness/strength testing (e.g., neurological, neuromuscular problems)?

If you answered YES to knee/joint problems or tendonitis, please explain: ____________

____

____ Have you recently had bleeding gums?

____ Have you recently experienced dental work?

PART VII: MEDICATIONS

Please indicate which of the following medications you take:

____ Allergy medications?

____ Hormones?

____ Anti-depressants?

____ Anti-anxiolytic (anxiety)?

____ Pain medication (e.g., asprin, Tylenol)?

____ Anti-inflammatory (e.g., ibuprofen, aleve)?

____ Antibiotics?

____ Sleep aids (e.g., ambien, lunesta)

Please list all medications (prescription and over-the-counter) you currently take:______________

____

Please list all vitamins and supplements you currently take (list dosage):_______________

____

What is your daily caffeine intake? (list # of cups/bottles/cans):_____________________________

____

Please list all ergogenic aids (performance enhancing), including those with stimulants (e.g., ephedrine, synephrine):____

____

If you answered YES to any of the medications above, please complete the following section:

What medication you answered yes __________________________

Are you currently taking the medication? __________________________

If no, how long ago did you stop? __________________________

What dosage are/were you taking? __________________________

How long were you taking the medication? __________________________

____ Have you had any sudden changes in diet to lose or gain weight?

____ Do you smoke now? If YES, packs per day? ____

____ Have you ever smoked in the past? If you have quit, how long ago? ____

The above facts are true to the best of my knowledge, and do not misrepresent my health in any way.

Signature of Participant:___________________________________ Date:________

Printed Name of Participant:_____________________________________

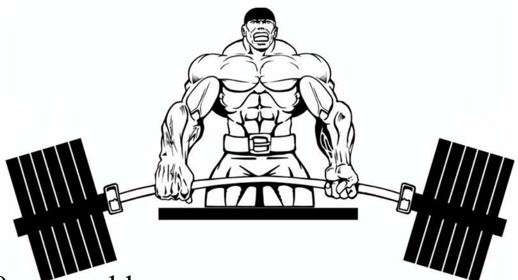
APPENDIX G

RECRUITMENT FLYER

Northern Illinois University
Learning Today, Leading Tomorrow

Do you want to increase your muscle mass?

Nutrition and Exercise Research Project-Fall 2014



Do I Qualify

- Males aged 18-30 years old
- More than 1 year of weight lifting experience
- Exclusion criteria includes:
  - Use of steroids within 1 year from start of study and use of performance enhancing supplements within 6 weeks from start of the study.
  - Allergy/intolerance to whey protein, gluten and/or glutamine, implanted electrical devices, sickle cell

What Do You Need To Do

- Ability to lift three to four times per week for about an hour each session for eight weeks
- Complete three sessions of strength measurements, body circumferences, and body-fat analysis pre, midway and post intervention

Why?

- To figure out if the use of a whey beverage after weight lifting has any impact on muscle size and strength

What Will You Get?

1. Free weight lifting program designed for muscle growth
2. Free supplement for after workout
   - Immediate for experiment group
   - Delayed for control group
3. Free analysis of diet
4. **Free** body composition analysis at end of study

Who to Contact?

- Anthony Nielsen: anielsen3@niu.edu
- Meagan O’Connor: MeaganProteinStudy@gmail.com

APPENDIX H

DIETARY ANALYSIS FOOD LOG

Dietary Food Log

Subject:

Date:

Day of the Week:

Time:	Food Type and Quantity

APPENDIX I

REVIEW OF LITERATURE

REVIEW OF LITERATURE

Muscle Contraction

Muscle tissue is very complex and is composed of many layers. The sarcomere is the smallest functional unit of a myofibril and contains the contractile proteins actin and myosin (Kenney, Wilmore & Costill, 2012). Sarcomeres line up end to end in long chains forming a myofibril, while large groups of myofibrils are known as a muscle fiber or cell. A fascicle then is a collection of muscle fibers and finally an assemblage of fascicles makes up the muscle body (Kenney, Wilmore & Costill, 2012).

The series of events that cause a muscle contraction is called excitation-contraction coupling (Kenney, Wilmore & Costill, 2012). A motor neuron which connects the brain and the muscle, once a signal travels down this nerve it links to the muscle at the neuromuscular junction. When the impulse reaches this junction it releases a neurotransmitter called acetylcholine (Ach), this chemical binds with the muscle and causes rapid depolarization, or change in the charge (Matthews, 2009). This depolarization results in an action potential to be transmitted throughout the length of the muscle (Matthews, 2009). The action potential causes sarcoplasmic reticulum (SR) to release large amounts of calcium. The sarcoplasmic reticulum is a system of tubules that run lengthwise within a muscle fiber surrounding each myofibril and stores calcium that is release once stimulated by an action potential (Kenney, Wilmore & Costill, 2012).Once the action potential is sent throughout the muscle it will begin to contract, the protein filaments that are responsible for contraction of the muscle are actin and myosin (Kenney, Wilmore & Costill, 2012).

Myosin is known as the thick filament and is surrounded by six different strands of the thin filament actin. For a muscle to contract myosin must attach to actin, this is accomplished by the “head” of the myosin filament. The myosin head is energized by adenosine triphosphate (ATP) and goes into a “cocked” position, when myosin attaches to the binding sites on the actin filament forming a cross-bridge the stored energy is liberated (Matthews, 2009). The energy released then causes a conformational change in the myosin head moving it back to its resting state, this pulls on the actin filaments shortening the sarcomere length. The pulling action of the myosin head on the actin filament is known as the power stroke (Kenney, Wilmore & Costill, 2012). The cross-bridge detaches once another ATP molecule binds with myosin returning it to the “cocked” position so this cycle can be repeated (Matthews, 2009). The repeated attachment and power stroke of the myosin on the actin causes the filaments to slide past one another, this is called the sliding filament theory (Kenney, Wilmore & Costill, 2012). Repetitively stressing this action will cause a muscle to adapt by hypertrophying or growing larger (Schoenfeld, 2013).

Muscle Hypertrophy

Muscle tissue exhibits great manipulability this distinctive feature allows it to adapt to both acute and chronic stimuli. Past research has concluded that an overload stimulus imposed on a muscle will cause an increase in the cross-sectional area (CSA) (Schoenfeld, 2013). This increase in the CSA can be described as muscle hypertrophy.

There are two ways to increase a muscles size, hypertrophy and hyperplasia. Hypertrophy refers to an increase in the size of existing muscle fibers, while hyperplasia is an increase in the total number of fibers (Kenney, Wilmore & Costill, 2012). Only a few studies have been completed on fiber hyperplasia in humans and it seems that it could be a contributing factor to overall increases in the cross-sectional area of a muscle (Larsson & Tesch, 1986). For now fiber hypertrophy seems to be the main contributor to increases in muscle size. Fiber hypertrophy can be explained by a few mechanisms, new actin and myosin filaments more myofibrils, additional cytosol, larger amounts of connective tissue or a combination of these mechanisms (Kenney, Wilmore & Costill, 2012).

In order for muscle hypertrophy to be examined one must breakdown the different muscle types. There are two separate types of muscle fibers in the human body, type I or slow twitch and type II or fast twitch. Type II fibers can be further broken down into type IIa and type IIx. This is important to distinguish because while both type I and II muscle fibers are capable of hypertrophy, type II fibers have generally have a greater hypertrophic response than type I fibers do (Gardiner, 2001). Type I fibers are called slow twitch because they take longer to reach peak tension than type II fibers do, type I take approximately 110 milliseconds to reach peak tension while type II fibers take around 50 milliseconds (Kenney, Wilmore & Costill, 2012). Type II fibers have a shortening velocity around nine to twelve times faster than type I fibers (Gardiner, 2001). ATPase is an enzyme in the body that breaks down ATP, which releases a large amount of stored energy. This ATPase activity is another distinguishable factor in fiber type, ATP is split more quickly in type II fibers than in type I this results in a faster recycling of the myosin cross-bridge in type II therefore more powerful contractions are possible in type II than in type I fibers (Kenney, Wilmore & Costill, 2012).

The sarcoplasmic reticulum's job is to store and release calcium once there is propagation of an action potential. To initiate a muscle contraction, calcium is released from the sarcoplasmic reticulum, which is cleverly located surrounding the contractile units of the myofibril (Matthews, 2009). Calcium is responsible for exposing the active binding sites on actin therefore a rapid release of calcium would yield a faster muscle contraction (Kenney, Wilmore & Costill, 2012). Gardiner (2001) sums up muscle fiber types ranging from solely type I to solely type IIx. The fiber type is based on so much variability such as sarcoplasmic protein compositions, enzymes of energy metabolism, calcium regulating proteins and all the possible combinations of protein isoforms which ultimately determine the functional properties of a muscle fiber (Gardiner, 2001).

Muscle hypertrophy is the most desired outcome of resistance training, this only occurs in the presence of a positive protein balance, this is called protein synthesis (Ivy & Ferguson, 2010). Resistance training does stimulate elevated levels of protein synthesis but it also promotes protein degradation. Protein degradation is the breakdown of proteins into simpler substances such as amino acids (Cooper, 2000) The balance between protein synthesis and degradation ultimately determines net gains in fiber hypertrophy. Due to exercise induced muscle damage protein degradation dominates until proper nutritional intake occurs, this will terminate catabolism or the breakdown and stimulate anabolism or build up for potential muscle hypertrophy (Ivy & Ferguson, 2010). Adequate amounts of protein and carbohydrates post workout are essential for stimulating protein synthesis and creating a positive protein balance that will lead to the repairment of damaged muscle (Ivy & Ferguson, 2010).

Resistance Training

Resistance training has long been sought out by many people to induce skeletal muscle hypertrophy, however many of these individuals are not aware of the mechanisms responsible for the changes that will occur due to weight training. Muscle contractions can be described in two different manners, static or isometric and dynamic or isokinetic. Isokinetic contractions are those that produce movement, and can further be broken down into concentric and eccentric. A concentric contraction is when the muscle shortens (Kenney, Wilmore & Costill, 2012). This action was described earlier with the sliding filament theory, the myosin filament pulls on the actin filament this causes the muscle to shorten, a concentric contraction. A muscle also generates force as it lengthens this is known as the eccentric contraction (Kenney, Wilmore & Costill, 2012). This action occurs when the actin filaments slide back to a resting position and the sarcomere returns to its original length. Static or isometric contractions are those that produce no movement. In an isometric contraction the muscle still generates force but no net movement occurs (Kenney, Wilmore & Costill, 2012).

Schoenfeld (2010) studied the effects of exercise induced skeletal muscle hypertrophy, showing that there are three main factors that determine the likelihood of muscle growth. These factors are mechanical tension, muscle damage and metabolic stress, each play an inherent roll in the hypertrophic response to resistance training. Mechanical tension refers to both the force generation and the stretch placed on the muscle. The tension created by resistance training is believed to disturb muscle cell integrity stimulating a mechano-chemical response that results in hypertrophy (Schoenfeld, 2010). The second factor, muscle damage, with resistance training can result in damage to the plasma membrane, the contractile proteins and even the supportive connective tissue in the muscle. This trauma has been associated with an inflammatory response that causes the body's immune system to rid the area of damaged tissue. This in turn increases satellite cell activity which promotes hypertrophy (Schoenfeld, 2010). Lastly metabolic stress is a component for hypertrophy. A higher metabolic stress with moderate muscle tension can have a significant effect on the rate of muscle hypertrophy (Schoenfeld, 2013).

McCall, Byrnes, Dickinson, Pattany, and Fleck (1996) studied the effects of resistance training on hypertrophy using 15 male college aged subjects with a twelve-week training program. Post-training the subjects showed a 25% increase in one repetition maximum (1-RM) on the preacher curl (McCall et al., 1996). A one repetition maximum is the greatest amount of weight that can be lifted in a single all-out effort (Kenney et al., 2012). Also there was a significant increase in the cross-sectional area, the bicep had a 12.6% increase while the tricep yielded a 25.1% increase, this is equivalent to a 14.6% increase in the cross-sectional area of the total arm (McCall et al., 1996). These results were broken down further to find a 10% increase in type I fibers and a 17.1% increase in type II fibers. While both type I and type II fibers illustrated a hypertrophic response to training stimuli this study shows that type II fibers have a greater capacity for growth. This concurs with the findings of Gardiner (2001) who also found that type II fibers have a more adept ability for hypertrophy than type I fibers. This demonstrates that resistance training that includes both concentric and eccentric actions is capable of producing hypertrophic results as well as increases in one repetition maximum strength (McCall et al., 1996).

Training intensity or load, has long thought to be a major determinant in muscle hypertrophy. Basic hypertrophy specific training protocol uses 60-85% of an individual's 1-RM with an 8-12 rep range to maximize hypertrophic effects (Abe et al., 2012). Schoenfeld (2013) examined if there was a minimum threshold that needed to be reached for muscle growth to be initiated. The results showed that there is a minimum threshold that needs to be reached to maximize the exercise induced hypertrophic response, however the precise load is yet to be determined (Schoenfeld, 2013). There was significant hypertrophy recorded in untrained subjects using low intensity exercise (< 60% of 1RM), although there is no clear data to illuminate if the same results would occur in trained subjects. Schoenfeld (2013) found that the issue of low load exercise seemed to be the recruitment of sufficient numbers of motor neurons to prompt muscle hypertrophy. During the 16-week protocol subjects were trained to volitional muscular fatigue in an effort to recruit as many possible motor units to enhance post exercise protein synthesis. Due to training to failure for 16 consecutive weeks could have caused a state of over training in the individuals and thus skewed the end results (Schoenfeld, 2013).

A similar study conducted by Burd, Mitchell, Churchward-Venne & Phillips (2012) found comparable results using resistance trained males. Two groups were used in this study one of low intensity, training 30% of their 1-RM, and the other high intensity, training at 90 % of their 1-RM. The low intensity group trained leg extensions to momentary muscle failure, the higher intensity group just performed the given sets and repetitions due to the increased training load. Burd et al. (2012) study found that using a load of 30% of a one repetition maximum produced nearly identical levels muscle protein synthesis during the first 4 hours of recovery as the 90% one repetition maximum. Additionally the lower intensity subjects continued to display greater levels of protein synthesis after 24 hours than the higher intensity group (Burd et al., 2012).

Higbie, Cureton, Warren III, & Prior (1996) sought out the different effects on muscle strength, hypertrophy and neural activation between concentric and eccentric contractions. The study was 10-weeks and used 60 women, they were divided up into concentric only, eccentric only and control. Higbie et al. (1996) found that when strength was measure eccentrically the concentric group showed a 12.8% increase, the control group a -1.7% decrease and the eccentric group had a 36.2% increase. Strength was also measured in a concentric manner as well showing a 6.8% increase in the eccentric group, a 4.7% increase in the control group and 18.4% increase in the concentric group (Higbie, Cureton, Warren III & Prior, 1996). Cross-sectional area was measured to determine the hypertrophic results the eccentric group had a 6.6% increase while the concentric group had a 5.0% increase, there was no increase in cross-sectional area measured in the control group (Higbie, Cureton, Warren III & Prior, 1996).

Building on Higbie et al. (1996), Farthing & Chilibeck (2003) comparing eccentric training and concentric training, using repetition speed as a variable. The training groups consisted of eccentric fast (180 s-1) and eccentric slow (30 s-1), the concentric fast (180 s-1) and concentric slow (30 s-1). These velocities were achieved using a isokinetic strength Biodex dynamometer (Farthing & Chilibeck, 2003). A dynamometer is an apparatus used to measure mechanical force and is widely thought of as the gold standard for testing muscular strength (Tsiros et al., 2011). There was a 13% increase in cross-sectional area for the fast eccentric, a 5.3% increase in the slow concentric group, 2.6% in the fast concentric group, the slow eccentric group had a higher increase than the fast concentric but not the slow concentric. From this it seems higher velocity eccentric training yields superior results in strength and hypertrophy when compared to slow eccentric and both repetition speeds of concentric training (Farthing & Chilibeck, 2003).

A study done in 2006 by Gillies, Putnam & Bell looked at time under tension to promote increases in muscle mass. Gillies et al. (2006) study used 28 female subjects with previous strength training experience, they performed lower body exercise with the long concentric doing a 6-second concentric action and a 2-second eccentric action while the long eccentric did a 2-second concentric and 6-second eccentric (Gillies et al., 2006). There were drastic increases in maximal strength on the leg press in both groups as well as changes in muscle cross-sectional area. Using immunohistochemical analysis illustrated that both the groups experienced increases in cross-sectional area of type I fibers. However, only the long concentric group demonstrated an increase in size for type II fibers, the long eccentric groups type II fiber size actually seemed to decrease slightly (Gillies, Putnam & Bell, 2006). This is similar to the findings of Farthing & Chilibeck's (2003) study on repetition velocity. They concluded that slow concentric actions result in a higher tension in the muscle than fast concentric, while fast eccentric actions have higher tension than slow eccentric (Farthing & Chilibeck, 2003). This is also in agreement with Schoenfeld's (2010) study in which one of the criteria for inducing muscle hypertrophy was mechanical tension. Mechanical tension was defined as the force generation created by the contraction of muscle as well as the stretch placed on the muscle (Schoenfeld, 2010).

Protein

Proteins are extremely multifaceted macromolecules that are utilized in nearly all biological processes (Berg, Tymoczko & Stryer, 2002). Proteins are capable of transporting and storing other molecules, they serve various immune functions, some proteins are enzymes to help catalyze chemical reactions, they produce movement through the contractile proteins of muscle, and proteins also conduct nerve impulses (Berg, Tymoczko & Stryer, 2002). Proteins are nitrogen containing compounds that are all composed of combinations of 20 different amino acids (Kenney et al., 2012). These amino acids can further be broken down into essential and nonessential. Essential amino acids are those the human body cannot produce them in sufficient quantities, therefore they must be taken in through food sources (Kenney, Wilmore & Costill, 2012). While nonessential amino acids are those that the body can synthesize in adequate amounts so dietary intake is not relied on for their supply (Kenney et al., 2012).

One of the most important amino acids is leucine. Leucine is one of the essential amino acids and is specifically tied to increasing muscle protein synthesis (Devkota & Layman, 2010). Leucine is also capable of elevating diet induced thermogenesis, due to increased protein anabolism and amino acid absorption/transport which both have huge energy expenditures (Devkota & Layman, 2010). The combination of increased muscle protein synthesis and thermogenesis translates to the preservation of current muscle mass, the anabolic potential to build new muscle tissue, and increased amounts of fat loss due to the sparing of lean tissue (Devkota & Layman, 2010).

Another key amino acid is glutamine, which is the most abundant amino acid in the body (Lanhan-New, Stear, Sherreffs & Collins, 2011). Glutamine is effective in resynthesizing muscle glycogen stores as well as elevating growth hormone levels, which consequently stimulates muscle protein anabolism (Candow, Chilibeck, Burke, Davison, & Smith-Palmer, 2001). Glutamine has been shown to increase intramuscular glycogen concentrations; these elevated concentrations could possibly decrease the likelihood of amino acid release from muscle during exercise thus inhibiting muscle protein catabolism (Candow et al., 2001).

There are two main types of protein, complete and incomplete proteins. Complete proteins are those found in animal sources like meat, fish, eggs, and milk, while incomplete proteins are those found in vegetable sources such as grains (Kenney et al., 2012). Milk proteins, complete proteins are the most common form for supplementation and there are two types, whey and casein. Whey is a complete protein containing abundant amounts of amino acids including high concentrations of leucine, also whey has an extremely high bioavailability so it digests rapidly (Hoffman & Falvo, 2004). Casein is also a complete protein, rather than digesting fast like whey, casein forms a gel like substance when consumed which provides a slow release of amino acids into the blood stream (Hoffman & Falvo, 2004). Soy is the most commonly used vegetable protein, or incomplete protein, which comes from soybeans. Soy is the only complete vegetable protein with a rather high concentration of branched chain amino acids (Hoffman & Falvo, 2004). Exercise has a high energy cost, thus people engaged in regular exercise have higher daily protein needs than sedentary individuals.

The recommended dietary intake for protein is 0.8 grams per kilogram of bodyweight for sedentary individuals this is approximately 15% of total calories consumed per day (Kenny, Wilmore & Costill, 2012). However due to the muscle damaged induced from exercise seen in athletes, their dietary intake for protein is much greater. Lemon (1998) found that endurance athletes have a higher amino acid oxidation rate due to the prolonged aerobic nature of their training. To recover from chronic strenuous endurance training the athlete should ingest between 1.2 and 1.4 grams of protein per kilogram of bodyweight (Lemon, 1998). It has been shown that strength trained individuals require increased protein intake due to the immense structural damage the muscle incurs from weight training, increased protein consumption is needed to support elevated protein synthesis rates as well (Lemon, 1998). It is recommended that the dietary requirement for protein in individuals engaging in strength training is as high as 1.6 to 1.7 grams per kilogram of bodyweight (Lemon, 1998).

Kreider (1999) found similar results to Lemon's (1998), however Kreider added a new piece to the puzzle. He stated that adding a carbohydrate to a post-workout protein shake would elevate levels of insulin and growth hormone providing a more anabolic environment to speed up recovery time (Kreider, 1999). The co-ingestion of carbohydrates and amino acids is highly effective because of the associated insulin response that minimizes muscle protein catabolism and the difference between muscle protein anabolism and catabolism ultimately determines muscular development (Gelfand & Barret, 1987). In addition, Kreider (1999) concluded that ingesting carbohydrates and protein prior to exercise has the potential to reduce the catabolism that occurs during intense exercise.

It is known that protein requirements for athletes exceed those of sedentary individuals due to the exercise induced muscle damage of resistance training or the increased rates of amino acid oxidation from endurance training (Kreider, 1999; Lemon, 1998). However, is the timing of this excess protein crucial for maximizing human performance, Cribb & Hayes (2006) examine this question. Using two different test groups, one consumed protein pre-workout and post-workout and the other group consumed their protein supplement in the morning and evening. The pre-workout and post-workout group demonstrated greater increases in one repetition maximum strength than the morning and evening group on the squat, bench press, and deadlift.

The pre-workout and post-workout group had greater increases in lean body mass and decreased body fat percentage than the morning and evening subjects. Fiber cross-sectional area turned out no different, the pre- and post- group had significantly greater increases in size of type IIa, type IIx fibers and contractile proteins than morning and evening. From Cribb & Hayes (2006) study it can be concluded that supplementing protein pre- and post-workout out has a substantial effect on strength, body composition and hypertrophic potential when compared to supplementing at other times of day (Cribb & Hayes, 2006).

Esmarck, Anderson, Olsen, Richter, Mizuno & Kjaer (2001) performed a similar study on the effects of protein timing using elderly men. One group was to receive protein immediately post-workout and the other group received a protein supplement two hours post-workout. The group that received protein immediately post-workout had significant increases in peak torque as well as five repetition maximum (5-RM), while the two hours post-exercise group demonstrated only minor increases in a five repetition maximum. Additionally the immediate group had substantial increases in muscle cross-sectional area and mean fiber area, where as the delayed protein group showed no drastic changes in either cross-sectional area of mean fiber area (Esmarck et al., 2001).

Adequate protein intake is crucial to maximizing hypertrophic effects, increasing gains in muscle strength and promoting a positive protein balance (Kreider, 1999; Lemon, 1998). The timing of protein supplementation has also been found to be a essential to boosting the effects of resistance training (Esmarck et al., 2001; Cribb & Hayes, 2006). This is due to the post-workout induced sensitivity of a muscle to nutritional supplementation, for approximately 30-60 minutes post-exercise muscle tissue has an elevated ability to absorb nutrients (Ivy & Ferguson, 2010).

Ingesting nutrients during this "window" of increased muscle sensitivity does two things it slows protein catabolism and helps elevate protein synthesis; in order to induce muscle hypertrophy the body must be building more proteins than it is breaking down (Ivy & Ferguson, 2010). Esmarck et al. (2001) used a group of men who received a protein supplement two hours post-workout, this group demonstrated no increases in muscle CSA and only minor improvement in 5-RM strength. While the other group in this study received protein immediately post-workout, showed large increases in muscle CSA and 5-RM strength. Additionally Cribb & Hayes (2006) used two groups of subjects, one receiving a protein supplement pre- and post-workout while the other was instructed to consume the protein supplement morning and evening. The pre- and post-workout group had larger increases in 1-RM strength on the bench press, squat and deadlift when compared to the morning and evening group. Also the pre- and post-workout subjects had increases in lean body mass while having reductions in body fat percentage. C ribb & Hayes (2006) and Esmarck et al. (2001) study's both show the importance of protein timing which is in correlation with Ivy and Ferguson's (2010) exercise induced elevations in muscle sensitivity to nutritional stimuli for 30 to 60 minutes post-exercise.

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