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Effects of an Amylopectin-Chromium Complex Plus Whey Protein on Strength and Power After Eight Weeks of Resistance Training

Original Research

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Abstract

Background: Previously we reported that acute supplementation with an amylopectin-chromium complex combined with a six-gram dose of whey protein increased rates of muscle protein synthesis. The purpose of this study was to examine if chronic supplementation with the same amylopectin-chromium complex plus a higher dose of protein could impact resistance training adaptations, recovery, and biomarkers of safety.

Methods: Using a randomized, active-controlled, double-blind design, 35 recreationally active men (mean ± age, height, weight: 40.9 ± 7.6 y, 180.2 ± 6.1 cm, 95.8 ± 14.5 kg) were matched according to HOMA-IR and resistance-training experience and then randomly allocated to one of three groups: an active group consisting of 2 g amylopectin-chromium complex + 15 g whey protein isolate (V15P), an equivalent dose of whey protein isolate (15 g of whey protein, 15P), or a 30 gram dose of whey protein isolate (30P). Subjects consumed their respective supplement immediately following resistance exercise on days when training occurred and at the same time of day on non-training days. At 0, 4, and 8 weeks of training, body composition (4C via DXA, Bod Pod, Bioimpedance), whole-body protein balance (oral ^{15}N-alanine), upper body and lower body performance (bench press, squat, jump power), and visual analog scale (VAS) scores for recovery, sleep quality, energy, willingness to train, and muscle soreness were assessed. Safety assessments included systemic hemodynamics, complete blood count, and comprehensive metabolic panels.

Results: All groups gained strength, increased fat-free mass, and improved muscle size. Similarly, all groups increased squat repetitions to failure (RTF), with V15P experiencing a greater increase (+25.3 reps, $p = 0.02$) when compared to 15P (+12.0 reps) and 30P (+13.9 reps). After normalizing data to body mass, vertical jump power increased ($p = 0.03$) more for V15P (+2.1 Watts/kg) than either 15P (+0.4 Watts/kg) or 30P (+0.3 Watts/kg). Vertical jump height calculated from power output increased more in V15P (+8.7 cm, $p = 0.04$) than 15P (+1.6 cm) and 30P (+0.9 cm). Net protein balance was greater ($p = 0.04$) in V15P compared to 15W and 30W at four weeks ($p < 0.05$), but this difference was not observed after eight weeks ($p = 0.51$). No changes in VAS were identified between groups. Diastolic blood pressure decreased in V15P ($p = 0.002$) compared to the other groups, and outside of an interaction for creatinine and aspartate aminotransferase (which still remained well within clinical limits), all blood-based markers of safety demonstrated no differences between groups.

Conclusions: These findings indicate the V15P increased lower-body muscular endurance and power (e.g. squat RTF, vertical power, vertical jump) potentially through optimization of early adaptations in whole-body protein balance, neuromuscular physiology or increased energy intake, but it did not augment changes in FFM or muscle

size in comparison to protein alone. Additionally, it appears that V15P may decrease diastolic blood pressure.

Key Words: insulin, chromium, insulin sensitivity, muscle protein synthesis, amino acids
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Introduction

The role of protein in promoting greater adaptations to resistance training has been well documented (1). Two recent meta-analyses, one by Cermak (2) and another by Morton (3) highlighted the ability of protein, when combined with a resistance training program, to increase strength and fat-free mass accretion. In addition, previous work has illustrated that optimal doses of protein (with respect to increases in muscle protein synthesis) likely range between 20 – 40 grams per serving depending on subject age (4-6), protein quality (7), and the amount of muscle mass activated during exercise (8).

Interest surrounding what dose is considered adequate has led to investigations which have explored the efficacy of smaller protein doses with various combinations of other nutrients. For example, Churchward-Venne and colleagues (9) determined the muscle protein synthetic response to a combination of added leucine, an essential amino acid with known insulinogenic properties (10), a mixed macronutrient beverage, and a suboptimal (6.25 grams) dose of whey protein isolate. Their results indicated that a combination of low dose whey protein (approximately 25% of the dose previously shown to maximally stimulate MPS), added leucine, and a mixed macronutrient beverage was as effective as a 25-gram dose of whey protein in stimulating postprandial rates of muscle protein synthesis (9). Later, Ziegenfuss and investigators (11) published data which illustrated greater rates of myofibrillar muscle protein synthesis four hours after completing a single bout of leg extension exercise (8 sets of 10 repetitions at 80% one-repetition maximum) and ingesting a combination of six grams of whey protein isolate and two grams of an amylopectin-chromium complex in comparison to consuming an isonitrogenous dose of whey protein. While more information is needed surrounding the mechanism(s) of this combination of nutrients, previous research has indicated the potential for chromium to favorably influence insulin signaling, substrate oxidation, and body composition (12-15). The majority of research in humans, however, has reported limited benefits of chromium on changes in exercise performance and body composition (16-19). While insulin is known to play a permissive role in muscle protein metabolism (20), its potential to attenuate muscle protein breakdown rates (21) when combined with whole protein or essential amino acids (4, 10, 22) requires more investigation. Indeed, results from these kinds of studies are valuable as they offer insight into the potential ability to increase muscle protein accretion without delivering as high of a protein dose as currently recommended. Towards this end, lower doses of dietary protein have several theoretical benefits. For example, individuals who are cutting calories or trying to maximize strength-to-bodyweight ratios may not want to consume additional protein due to its caloric load. Also, for many people smaller doses of protein are typically easier to digest. And finally, getting adequate (let alone optimal) amounts of calories and protein is typically difficult in older and clinical populations. Ironically these groups have greater rates of anabolic resistance (23, 24), which puts them at an increased risk of sarcopenia (myopenia) and its associated comorbidities. Thus, strategies that can enhance amino acid uptake into muscle, increase muscle protein synthesis, and enhance training adaptations are of great interest.

While offering valuable insight, the aforementioned studies have limited external validity due to their acute nature and utilization of single feedings and single bouts of resistance exercise. Additionally, there is ongoing debate regarding the ability of acute muscle protein synthesis outcomes to translate into phenotypic changes in strength and fat-free mass (25). As such, more research is needed to explore the efficacy of consuming protein in combination with nutrients that may heighten anabolic effects and potentially improve performance and fat-free mass accretion. Therefore, the purpose of this study was to investigate the efficacy of ingesting two different doses of whey protein isolate (15 and 30 grams, respectively) in comparison to a group that ingested two grams of an amylopectin-chromium complex and a 15-gram dose of whey protein isolate on changes in muscle performance, protein homeostasis, and body composition. It was hypothesized that the combination of the amylopectin-chromium complex and whey protein would yield greater performance and body composition outcomes compared to a 15-gram

dose of whey protein alone, while promoting similar changes in performance and body composition to the 30-gram dose.

Methods

Experimental Approach

This investigation utilized a randomized, double-blind, parallel group study design. Healthy men between the ages of 35 – 55 years were pre-screened using health history questionnaires, physical examination including vital signs and blood work prior to being enrolled in the study. Once determined to be eligible and to help control for cohort differences in neuromuscular and metabolic physiology, participants were matched according to baseline resistance training experience and Homeostatic Model Assessment of Insulin Resistance (HOMA-IR). Training status is accepted as an important variable that can impact neuromuscular changes that occur at the start of a training program (26) and HOMA-IR values have been shown to correlate with insulin resistance and may be impacted by whey protein and/or chromium ingestion (27). After matching, participants were randomly assigned in a double-blind fashion to ingest on a daily basis either two grams of an amylopectin-chromium complex and 15 grams of whey protein isolate (V15P), 15 grams of whey protein isolate (15P), or 30 grams of whey protein isolate (30P). Subsequently, participants completed three near identical study visits at similar times of the day after 0, 4, and 8 weeks of supplementation. Each of these visits consisted of dietary recall, venous blood draw, circumferences, body composition, whole-body protein metabolism, lower-body power, upper-body strength, upper-body power, upper body muscular endurance, lower-body strength and lower-body muscular endurance. Prior to each visit, participants were required to report to the laboratory after observing a ten hour fast, replicating their dietary intake for a 24-hour period, and avoiding exercise for 48 hours. Additionally, compliance to all elements of the study design (diet, exercise, and supplementation) was evaluated weekly and changes in sleep quality, energy, recovery, and willingness to exercise were assessed using visual analog scales (VAS) and validated qualitative psychometric indices.

Table 1. Overview of Research Design.

Procedure	Screening	Visit 2 (Week 0)	Visit 3 (Week 4)	Visit 4 (Week 8)
Informed Consent	X			
Inclusion/Exclusion Criteria	X			
Medical History	X			
Physical Exam (Including EKG)	X			
Height and Weight	X			X
Hemodynamics	X			X
Safety Screen (CMP, CBC, Lipids)	X			X
Diet Control	X	X	X	X
Body Composition		X	X	X
^{15}N-Alanine Whole Body Protein Balance		X	X	X
Visual Analog Scales		X	X	X
Perceived Recover Questionnaire		X	X	X
Muscular Strength		X	X	X
Muscular Endurance		X	X	X
Bench Press Power		X	X	X
Vertical Jump and Lower Body Power		X	X	X
Circumferences		X	X	X
Insulin	X	X	X	X
3-Day Food Record Analysis		X	X	X
Protocol Compliance		X	X	X
Adverse Event Monitoring	X	X	X	X

Study Participants

Thirty-five healthy men (mean ± SD: 40.9 ± 7.6 years, 180.2 ± 6.1 cm, 95.8 ± 14.5 kg, 29.4 ± 3.4 kg/m^2) were recruited to participate in this study. All participants read and signed an IRB-approved informed consent document prior to their participation in the study (Protocol # N21-VEL-001-2019, Integreview, Austin, TX; approval date: October 31, 2019). All study participants were required to be in good health

as determined by review of their medical history and routine blood chemistries. Inclusion criteria indicated that all participants were between the ages of 35 – 55 years, had body mass index levels between 25 – 34.99 kg/m^2, were normotensive (systolic pressure between 100 – 139 mm Hg and diastolic pressure between 65 – 89 mm Hg) with a normal resting heart rate (≤90 beats/min). Additionally, participants had to agree to refrain from exercise for 48 hours, replicate their diet for 24 hours, abstain from caffeine and alcohol for 24 hours, and observe a ten hour fast prior to each study visit. Potential participants were excluded if they had a history of diabetes, smoking, malignancy (except non-melanoma skin cancer) in the previous five years or any other clinical condition that the researchers felt would compromise their safe participation. Individuals who recently lost more than ten pounds, had prior bariatric procedures or were diagnosed or were being treated for any chronic inflammatory (e.g., Lupus, HIV/AIDS, ulcerative colitis), gastrointestinal, or metabolic (diabetes) condition or disease were also excluded. Participants who were currently consuming any nutritional product deemed to have anabolic or anti-catabolic properties (including anabolic steroids) with the exception of a multivitamin and fish oil were excluded. A CONSORT diagram is provided as figure 1 for all study participants through the study protocol.

Figure 1. Consolidated Standards of Reporting Trials (CONSORT) Diagram

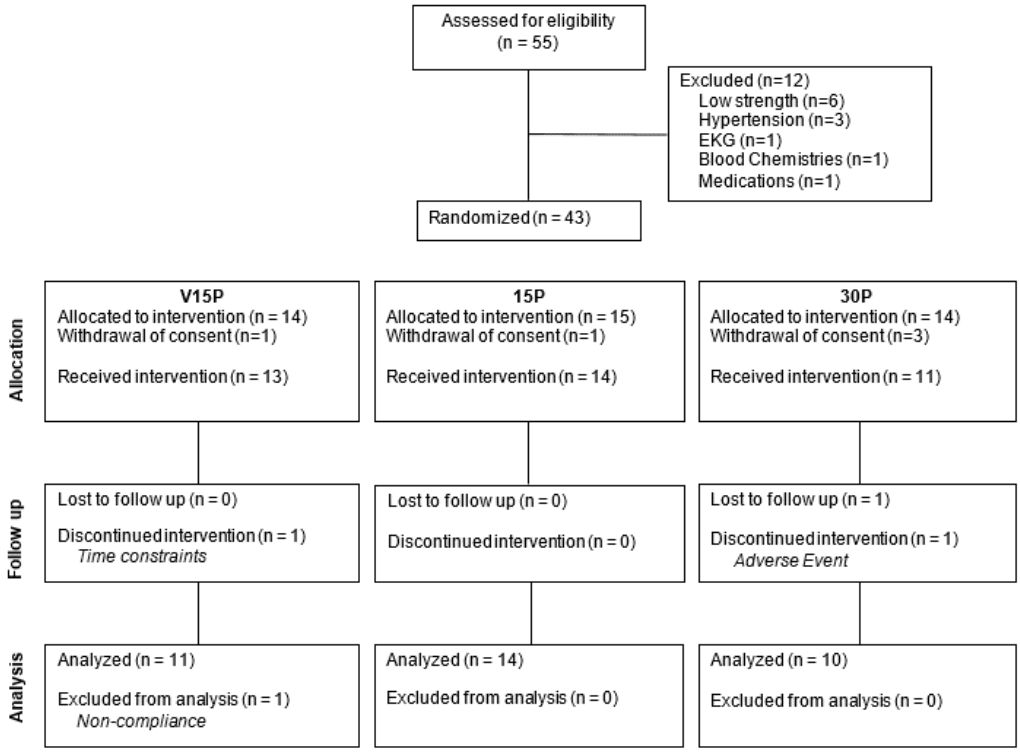


Table 2. Study Participant Demographics.

Group	Age	Height (cm)	Weight (kg)	Body Mass Index (kg/m^2)
V15P	41.9 ± 8.0	180.1 ± 5.5	92.2 ± 13.5	28.3 ± 3.2
15P	39.2 ± 7.1	182.3 ± 6.2	101.4 ± 12.0	30.5 ± 3.1
30P	42.0 ± 8.3	177.4 ± 5.9	92.0 ± 17.3	29.0 ± 3.8
Total	40.9 ± 7.6	180.2 ± 6.1	95.8 ± 14.5	29.4 ± 3.4

V15P (n=11); 15P (n=14); 30P (n=10)

Anthropometrics and Hemodynamics

Standing height was determined using a wall-mounted stadiometer with each study participant in their socks with heels together. Body weight was measured using a Seca 767™ Medical Scale (Hamburg, Deutschland). Resting heart rate and blood pressure were measured in duplicate using an automated blood pressure cuff (Omron HEM-780).

Dietary and Physical Activity Controls

To replicate baseline testing conditions, study participants were asked to complete a 24-hour dietary recall and follow an identical pattern of dietary intake for the 24-hour period prior to each study visit while also observing an overnight (10-hour) fast. Baseline dietary recalls were copied and given back to study participants to be used as a guide to replicate their food intake prior to their subsequent study visits. In addition, study participants were asked to complete non-weighed 3-day (two weekdays, one weekend day) food records prior to their scheduled study visits after 0, 4, and 8 weeks of supplementation. During enrollment, subjects received instruction on how to determine serving sizes using standard dietetic models and written examples. For all dietary assessments, subjects were asked to be as detailed as possible regarding type of preparation, serving size, and breaking down ingredients within a combined meal while also being told to include all snacks and beverages with calories. To control for exercise activity prior to each visit, study participants scheduled each subsequent study visit no sooner than 48 hours after training. All three-day dietary records were averaged and analyzed by the same research team member using the clinical edition of NutriBase IX (Phoenix, AZ).

Venous Blood Collection and Processing

Whole blood and serum samples were collected using standard phlebotomy techniques during all study visits. Whole blood samples were collected into K_2-EDTA treated Vacutainer tubes. Upon collection, each sample was slowly inverted ten consecutive times prior to immediate refrigeration. Serum samples were collected in serum separation tubes and allowed to clot for 30 minutes at room temperature prior to being centrifuged (Horizon mini E Centrifuge, Drucker Diagnostics, Port Matilda, PA) for 15 minutes at 3,200 rpm. For screening purposes, blood collected at visit 1 was analyzed for a comprehensive metabolic panel, complete blood count with platelet differentials, and lipid panel. Components of the comprehensive metabolic panel consist of glucose, blood urea nitrogen [BUN], creatinine, aspartate aminotransaminase [AST], alanine aminotransaminase [ALT], creatine kinase, lactate dehydrogenase, total bilirubin, alkaline phosphatase [ALP], uric acid, sodium, potassium, total protein, albumin, globulin, and iron. Complete blood counts were analyzed for absolute cell number and percentage of contribution for neutrophils, eosinophils, basophils, lymphocytes, and monocytes in addition to overall white blood cell and red blood cell count, hemoglobin, hematocrit, mean corpuscle volume, mean corpuscle hemoglobin, red cell dimension width, and mean corpuscle hemoglobin content. Lipid panel components consist of triglycerides [TG], total cholesterol [TC], LDL cholesterol, and HDL cholesterol. All analyses were completed using automated clinical chemistry analyzers (LabCorp, Dublin, OH branch). Additionally, insulin concentrations were determined via ELISA techniques at LabCorp. All samples from the same day were batch analyzed with test-retest reliabilities commonly reported using internal quality control data from clinical laboratories and associated automated analyzers within a range of 3 – 5% (28).

Circumferences

All arm, chest, and mid-thigh circumferences were assessed by the same two trained investigators using the same flexible tape measure with an attached tensiometer to ensure consistent application of tension before (week 0) and after eight weeks of supplementation and training. Additionally, consistent application of assessment technique was applied for all study investigators completing these measurements. Three measurements were taken on the right side of the body at each site and the two closest measurements were averaged. Each measurement was visually assessed to ensure the tape measure stayed level laterally and anteriorly/posteriorly (29). Finally, standardized criteria were used to anatomically identify where measurements occurred. Arm circumference was measured at half the distance between the olecranon process of the ulna and acromion process of the scapula. The shoulder was abducted in a position perpendicular to the torso with the elbow passively flexed at 90 degrees. Chest circumference was measured at the level of the participant's nipples. A deep breath was taken and exhaled. After exhalation, the measurement was taken. Mid-thigh circumference was measured halfway between the most superior border of the patella and anterior superior iliac spine. Each measurement was taken with the knee slightly bent while relaxed. Coefficients of variation for these measurements ranged from 0.87 (chest) to 0.95 (arm, mid-thigh).

Body Composition

Lean mass, fat mass, percent fat, and android/gynoid ratio were determined by dual-energy x-ray absorptiometry (DXA; General Electric Lunar DPX Pro) at 0, 4, and 8 weeks of supplementation. All DXA scans were performed by the same technician and analyzed by the manufacturer's software (enCORE version 13.31). Briefly, subjects were positioned in the scanner according to standard procedures and remained motionless for approximately 15 minutes during scanning. DXA segments for the upper and lower limbs and trunk were directed using standard anatomical landmarks. Percent fat was calculated by dividing fat mass by total scanned mass. Lean to fat mass ratio was computed using a simple ratio between the two values. Quality control calibration procedures were performed prior to all scans using a calibration block and procedures provided by the manufacturer. Previously test–retest reliability using intra-class correlation coefficients for repeated measurements of lean mass, bone mineral content, and fat mass using this DXA were found to be $\geq$0.98 (30).

To measure total body water, intra and extracellular fluids, bioimpedance spectroscopy (BIS) was performed (ImpediMed SFB7). The SFB7 model scans 256 frequencies between 3 kHz and 1000 kHz and uses Cole modelling with Hanai mixture theory to determine total body water, extracellular fluid, and intracellular fluid. Following a 5-minute supine resting period, four electrodes were placed on the left side of the subject's body according to manufacturer recommended guidelines. The initial placement of electrodes was measured and recorded for each participant to replicate positioning during future visits. BIS was measured twice at each time point and the average value was used for data analysis. Intra-class correlation coefficients for repeated measurements of all fluid volumes were >0.97.

Body density (BD) was determined using air-displacement plethysmography (BOD POD® version 5.2.0, COSMED Concord, CA USA) which was calibrated according to instructions provided by the manufacturer before each test. Briefly, calibration was completed prior to each participant, first against the empty chamber and next against a cylinder of a known volume (50.326 L). Body density (BD) was determined by assessing the air pressure and volume. Thoracic lung volume was estimated using the manufacture's software. All measurements were taken with participants first removing all metal and/or jewelry and wearing compression shorts and/or sports bra (females). Two trials were conducted to determine BV, however if the two measurements were not within 150 mL of each other, a third trial was performed. The ADP percent body fat (%BF) values were calculated from internal software using Siri's 2-C model [$\%BF = ((4.95/BD) - 4.50) \times 100$]. Intraclass correlation coefficients for repeated measurements of body volume and body fat in our laboratory were $\geq$ 0.98.

During each lab visit, a 4-compartment (4C) body composition model was employed using DXA, air displacement plethysmography (ADP; BodPod, COSMED USA, Inc., Concord, CA, USA), and BIS. All devices were calibrated the morning of each assessment in accordance with the manufacturer's guidelines. DXA, ADP, and BIS provide estimates of bone mineral content, total body volume, and total body water, respectively. These variables were entered into the 4C equation of Wang et al. (31) to determine FM, FFM, and body fat percentage (BF%) for each participant.

Whole-Body Protein Turnover

Due to budgetary limitations, whole-body protein turnover/balance was measured in a subset of study participants (n=15). The analysis was completed using a single-pool whole body method using oral ingestion of ^{15}N-alanine and 24-hour urine collection. In a similar fashion as what was previously reported with Berryman et al. (32) and Ferrando et al. (33), participants first provided a 24-hour urine prior to visit 2 to correct for any background isotope enrichment. The night before each study visit, volunteers then ingested a single dose of ^{15}N-alanine (99% enriched; Cambridge Isotope Laboratories, Andover, MA) at a dose of 4 mg^{15}N/kg body mass with the evening meal. After ingestion, volunteers fasted for the next 10 to 12 hours. Urine was collected during this entire time period, which ended with the first void the following morning. Nitrogen flux (Q; g N/24 h) was determined using urinary urea enrichment according to Fern et al. (34). Protein synthesis and breakdown were calculated according to Stein et al. (35).

$$Q = PS + N_{EX} \text{ and } Q = PB + N_{IN}$$

$$PB = Q - N_{IN} \text{ and } PS = Q - N_{EX}$$

$$NET = PS - PB$$

N_{EX} is the amount or urinary urea nitrogen excretion in the 24hr pool plus 10% to account for ammonia

excretion (36) and N_{IN} represents nitrogen intake calculated from a diet recall of the evening meal before ingesting the isotope. Enrichment of tracer to trace for ^{15}N-urea was determined using gas chromatography mass spectrometry (University of Arkansas Medical Sciences, Little Rock, AR).

Muscular Power

Lower body power was assessed after all resting measures were completed. Lower body power was assessed via body weight jump squats while tethered to a TENDO power analyzer. Three countermovement jumps were completed. For each jump, subjects were required to bend their elbows and place their hands on their hips. Each jump was recorded for peak power and average power. The average of all three jumps was calculated and used for statistical analysis. Approximately 60-90 seconds of rest was given between repetitions and three minutes rest was provided after completion of the third jump. From these data, jump height was calculated using the equation of Lewis (37, 38) using algebraic substitution of the original formula: Jump height (cm) = average power in watts – (23 * body mass in kg) + (1,393/21.2).

Upper body power was assessed after upper-body maximal strength was determined. Upper-body power was assessed through the completion of an explosive Smith machine bench press using 65% of each subject's 1RM. The unit consists of a position transducer that measures the rate of linear displacement providing velocity and acceleration in addition to power production. The TENDO unit was attached to the end of the Smith machine bar. Subjects laid flat on their backs on a bench with their feet on the ground and hands on the bar in a pronated grip. Grip width was standardized for all subjects and reproduced during follow up testing. Subjects lowered the bar (1-2 second eccentric action) until it lightly touched the chest slightly above the nipple line, and then explosively launched the bar vertically upwards. Three repetitions were completed and the highest average power and peak power were recorded. Previous studies have incorporated the use of a TENDO into their study design (39) and Stock and colleagues (40) have published data to indicate it is a reliable means of assessment.

Muscular Strength and Endurance

To assess maximal strength and muscular endurance, one-repetition maximums (1RM) were determined followed by a repetitions-to-failure test. The supine (horizontal) bench press was used to assess the upper-body while Smith machine squats were used to assess the lower-body. Full range of motion for all bench press repetitions started with the elbows in full extension and continued to the point where the bar touched the chest. Similarly, squat repetitions technique started with the knees fully extended until the thigh was parallel to the ground. All tests followed the National Strength and Conditioning Association guidelines (41). To assess 1RM, each subject first performed a warm-up set of eight repetitions at approximately 50% of the perceived 1-RM followed by a set of three repetitions at 70% of the perceived 1-RM. Thereafter, the subject performed single lifts at progressively heavier weights until failure. No more than five maximal attempts were completed in one testing session. The maximal weight achieved for both the bench press and back squat exercise using these procedures was considered their 1RM. Three minutes of rest were given between each maximal attempt.

To assess muscular endurance, a load equivalent to approximately 65% of their previously determined 1RM was used and each participant was instructed to complete as many repetitions as possible. Each subject completed a total of three sets, interspersed with 60 seconds of rest. A repetition was only counted if a full range of motion was utilized (as described previously), and once a participant began the set they could not rest for any longer than two seconds at any point throughout the set. The total number of repetitions for all three sets was used as a measure of upper body muscular endurance. Following the third set, three minutes of rest was given before completing the next assessment. All repetitions were supervised and counted by a study investigator. The total number of repetitions performed were recorded and considered to be the person's muscular endurance. The reliability of our test procedures in five healthy subjects performing these endurance tests ranged from 0.76 – 0.95, values that are similar to previously reported investigations (40, 42).

Visual Analog Scales and Perceived Recovery Scale

Visual analog scales (VAS) were completed by each study participant after 0 and 8 weeks of supplementation. All VAS were constructed similarly with a 100-mm line anchored by "Lowest Possible" and "Highest Possible" to assess subjective ratings of energy, sleep quality, willingness to exercise, and

soreness. VAS scales are commonly used across the muscle damage and soreness literature to assess perceptual changes (43, 44). Additionally, recovery was assessed using the scale of Laurent et al. (45) whereby a scale from 0 – 10 was presented to study participants. A score of zero represented "very poorly recovered / extremely tired" with an "expectation of declined performance" and a score of ten represented "very well recovered / highly energetic" with an "expectation of improved performance".

Resistance Training Program

Upon completion of their first study visit, participants were randomized into their respective groups and were required to follow a weekly resistance training program. The program was designed by a certified strength and conditioning specialist (CSCS) and all loading progressions and observed rest periods were the same for all participants. The workout was designed as a periodized, split-body, three-days-per-week resistance training program. Two upper-body and two lower-body workouts were completed on a rotating basis whereby approximately 48 hours separated the completion of each workout. Upper body workouts consisted of the following exercises: bench press, pull-ups or body rows, shoulder press, triceps extension, biceps curls, flat or incline dumbbell press, shoulder shrugs, dumbbell or barbell row, triceps dips, upright rows, dumbbell curls, and abdominal exercises, respectively. Lower body workouts consisted of squat, Romanian deadlifts, deadlifts, step-ups or split squats, good mornings or leg curls, walking lunges, and weighted calf raises. Aside from the bench press and squat (which were mandatory exercises for all subjects) exercise choices may have deviated between subjects to accommodate equipment availability, participant interest, etc. and participants were required to train with the same exercise throughout the entire study. For the bench press exercise, %1RM load assignment was used, but for all other loads, loading was used according to repetitions maximums, pre-determined repetition ranges and following previously instructed loading rules (i.e. 2 x 2 rule) which mirrored an autoregulation approach outlined by Mann and colleagues (46). Briefly, participants were instructed to increase their weight when they could perform two more repetitions than what was prescribed on two consecutive sets. Thus, a progressive approach was followed and as strength and endurance improved, training loads were increased to maintain recommended ranges. In general, exercises that involved multiple-joints and large groups of muscles were assigned to complete 3-5 sets of 6–10 repetitions. As the workout progressed, the prescribed volume was adjusted to maintain a periodized approach in a similar fashion for all study participants. Additionally, rest periods between exercises were two to three minutes for core movements involving heavier loads and lower repetitions (e.g. bench press, squat, deadlift) and one to two minutes between sets for all auxiliary exercises (biceps curls, abdominal exercises, triceps exercises, leg curls, calf raises, etc.) being completed for 10–15 repetitions. Each daily workout was not supervised by study investigators, however, study participants were given a training log to complete for each workout and each workout was signed off by a training partner or a member of the fitness staff and confirmed during weekly phone calls.

Supplementation Protocol

After enrollment, study participants were matched according to baseline HOMA-IR and resistance training experience and randomly assigned in a double-blind fashion to consume either: 2 grams of an amylopectin-chromium complex (Velositol®, Nutrition 21, Harrison, NY USA) + 15 grams of a whey protein isolate (V15P), 15 grams of a whey protein isolate (15P), or 30 grams of whey protein isolate (30P). All whey protein isolate was Instantized BiPro Whey Protein Isolate (BiPro USA, Eden Praire, MN USA). The 15-gram and 30-gram whey protein isolate groups were used as mid and high dose comparator groups, respectively. All provided supplements were prepared in powdered form, packaged in coded generic containers, and administered in a double-blind fashion. Participants were instructed to mix each supplement packet with eight fluid ounces of water immediately prior to oral dosing. All samples were manufactured per cGMP regulation of U.S. Title 21 CFR, section 111 in an FDA inspected facility, and a third-party analysis of the proteins was conducted by Eurofins Scientific. All attempts were made to blind and match all groups for appearance, color, aroma, and flavor, however, it is acknowledged that the volume of powder in the 30-gram group was two times the amount provided in the other two groups. Notably, the packets were non-translucent (foil lined) and all supplements were administered at home and away from study investigators. Additionally, only four study participants knew each other outside of the laboratory, so the ability for conversation to be shared surrounding any differences in what was contained in each packet was limited. Compliance in following the supplementation program was assessed by having participants return their empty protein packets and record their supplement use in a

daily supplement log. A representative supplement facts label for the amylopectin-chromium complex can be found as a supplementary figure and has been previously published (11).

Adverse Event Monitoring

All study participants were required to record any adverse events throughout the study. Participants were given a symptom questionnaire to complete during and after their completion of the study protocol to assess both the incidence and severity of adverse events according to CTCAE grading and MedDRA guidelines.

Statistical Analysis

All data were entered into two separate Microsoft Excel (Seattle, WA USA) spreadsheets (i.e. manual double-key data entry) and compared to assure data quality prior to analysis. SPSS version 23 (Armonk, NY USA) was used for all analyses. Normality assumptions were checked on all variables using a one-sample Shapiro-Wilk test. Non-normal distributions were transformed using natural logarithms, cubed, and square root transformations. Outliers were checked via visual inspection of studentized calculations on the residuals (threshold value of $\pm$ 3) of each dependent variable. One-way ANOVA were used to assess baseline differences. Separate analyses were completed to assess changes after four and eight weeks of supplementation. Separate 3 x 3 mixed factorial ANOVA with repeated measures on time were assessed for all outcomes after eight weeks of supplementation and 3 x 2 mixed factorial ANOVA with repeated measures on time were assessed for all outcomes after four weeks of supplementation. When the sphericity assumption was not met, the Greenhouse-Geiser correction was applied. In addition, delta values were computed and independent t-tests were completed to assess between-group differences using the delta values after four and eight weeks of supplementation. In instances where statistical trends and significance were identified, mean differences of the change scores and 95% confidence intervals were calculated on the difference between groups. Individual within-group effects were compared using paired samples t-test. All data are presented as means $\pm$ standard deviations. Effects were considered significant at $p \leq 0.05$ and trends were declared at $0.051 \leq p \leq 0.10$.

Results

Adverse Events

One out of the 13 participants assigned to V15P reported a mild adverse event possibly related to the treatment while one participant in the 30P group reported a moderate adverse event possibly related to study treatment. No adverse events were reported in the 15P group. All adverse events reported throughout the trial are provided in Supplementary Table 1.

Hemodynamics

No significant group x time interaction was identified for systolic blood pressure ($p = 0.23$). When each group was observed individually across time, V15P was the only group to exhibit a significant change (Delta: -5.00 $\pm$ 6.47 mm Hg, $p = 0.03$) while 15P (Delta: 3.86 $\pm$ 5.87 mm Hg, $p = 0.27$) and 30P (Delta: 3.20 $\pm$ 13.1 mm Hg, $p = 0.80$) exhibited non-significant increases. Individual groupwise comparisons revealed statistically significant differences between the observed changes in V15P and 15P (95% CI: -16.0, -1.7 mm Hg, $p = 0.02$) and V15P and 15P and 30P (95% CI: -15.9, -0.47 mm Hg, $p = 0.04$). Diastolic blood pressure exhibited a significant group x time interaction ($p = 0.002$), wherein V15P exhibited a significant decrease (Delta: -5.09 $\pm$ 8.07 mm Hg, $p = 0.05$) and 15P exhibited a significant increase (Delta: 6.93 $\pm$ 7.14 mm Hg, $p = 0.003$). Again, when individual comparisons were made between groups, the changes observed in 15P were significantly different than V15P (95% CI: -5.86, -18.2 mm Hg, $p < 0.001$) and 30P (95% CI: 0.30, 13.0 mm Hg, $p = 0.04$). Resting heart rate values exhibited no change throughout the study.

Supplementary Table 1. Summary of Adverse Events.

	V15P (n=13)	15P (n=14)	30P (n=11)	Screened subjects prior to allocation (n=55)
Severity				
Mild	1		1	2
Moderate				
Severe				
Relationship to Study Treatment				
Not related	1			1
Possible			1	
Definite				1
Relationship to Study Treatment				
Not related				
Possible				
Definite				
Body Systems and Adverse Events				
Renal & Urinary Disorder				
Nephrolithiasis; Kidney Stones	1			
Injury				
Procedural Injury; Peripheral Nerve Injury				1
Viral Infection				
Epstein-Barr Virus			1	
Surgical & Medical Procedures				
Presyncope; Vagal Reaction				1
Total Number of Adverse Events Experienced During Study	1	0	1	2
Total Number of Subjects Experiencing Adverse Events: n (%)	1/13 (8%)	0/14 (0%)	1/11 (9%)	2/55 (4%)

Body Composition

All body mass, body composition, and body water data can be found in table 3 and supplementary Table 3. DXA bone mineral content was the only variable to exhibit a significant group x time interaction effect ($p = 0.03$), but separate individual pairwise comparisons failed to identify significant differences between any of the treatment groups ($p > 0.05$). Group x time interaction effects for all other body mass, body composition (both 4-compartment and DXA), and body water variables failed to approach statistical significance ($p > 0.05$). Body mass ($p = 0.002$) and body mass index ($p = 0.002$) values did indicate a significant main effect over time. When using a 4-compartment approach, no measures of body composition exhibited significant main effects for time ($p > 0.05$) and only 4-compartment fat-free mass exhibited a significant group effect ($p = 0.02$). When viewing body composition data just from the DXA, several variables failed to exhibit group x time interaction effects, but did demonstrate significant main effects over time: DXA total scanned mass ($p = 0.002$), DXA fat-free mass ($p < 0.001$), DXA percent fat ($p = 0.04$), and body mass index ($p = 0.002$).

Table 3. Body Composition

Variables	N	Visit 2 (Week 0)	Visit 3 (Week 4)	Visit 4 (Week 8)		4-Week	8-Week
Body Mass (kg)							
V15P	11	90.3 ± 13.5	90.6 ± 13.4	90.9 ± 13.5	Group	0.15	0.13
15P	14	100.3 ± 11.5	101.3 ± 11.8	102.0 ± 11.5†	Time	0.04	0.002
30P	10	91.3 ± 18.1	91.7 ± 17.5	92.2 ± 17.8	G x T	0.45	0.35
4-Compartment Fat-Free Mass (kg)							
V15P	11	71.5 ± 9.3	69.1 ± 9.1	70.6 ± 7.5	Group	0.02	0.02
15P	14	76.7 ± 6.7	77.5 ± 5.9	77.3 ± 6.2	Time	0.23	0.24
30P	10	68.3 ± 9.8	66.5 ± 10.5	69.3 ± 9.4	G x T	0.31	0.40
4-Compartment Fat Mass (kg)							
V15P	11	18.9 ± 8.2	21.5 ± 11.2	20.3 ± 8.4	Group	0.62	0.61
15P	14	23.6 ± 9.8	23.8 ± 10.3	24.7 ± 10.5	Time	0.07	0.14
30P	10	23.0 ± 11.4	25.2 ± 13.1	22.9 ± 11.3	G x T	0.48	0.47
4-Compartment Fat Percentage (%)							
V15P	11	20.4 ± 7.0	22.9 ± 9.4	21.7 ± 6.7	Group	0.52	0.74
15P	14	22.9 ± 7.8	22.9 ± 7.8	23.6 ± 8.1	Time	0.09	0.77
30P	10	24.3 ± 7.6	26.7 ± 9.6	23.9 ± 7.4	G x T	0.41	0.35
DXA Bone Mineral Content (grams)							
V15P	11	3234 ± 412	3216 ± 406 #	3213 ± 414	Group	0.05	0.04
15P	14	3580 ± 425	3555 ± 454 #	3609 ± 455	Time	0.68	0.67
30P	10	3152 ± 368	3186 ± 373	3161 ± 370	G x T	0.009	0.03
BIA Total Body Water (Liters)							
V15P	11	51.8 ± 6.9	48.8 ± 9.4	50.7 ± 6.7	Group	0.08	0.07
15P	14	54.9 ± 5.4	55.5 ± 5.0	55.4 ± 4.6	Time	0.38	0.51
30P	10	50.3 ± 8.2	49.9 ± 7.0	50.8 ± 8.4‡	G x T	0.33	0.58
BIA Extracellular Water (Liters)							
V15P	11	21.83 ± 2.65	21.42 ± 2.45	21.90 ± 2.49	Group	0.11	0.18
15P	14	23.44 ± 1.99	23.11 ± 2.02	22.89 ± 1.82	Time	0.29	0.43
30P	10	21.52 ± 3.17	21.35 ± 2.59	21.62 ± 3.24	G x T	0.95	0.65
BIA Intracellular Water (Liters)							
V15P	11	30.0 ± 4.4	29.2 ± 3.8	28.8 ± 5.4	Group	0.13	0.05
15P	14	35.2 ± 13.7	32.4 ± 3.0	32.5 ± 3.0	Time	0.71	0.48
30P	10	28.7 ± 5.1	28.6 ± 4.5	29.2 ± 5.3†	G x T	0.30	0.75

† = Different than visit 2 ($p<0.05$); # = Different than 30P.

Performance

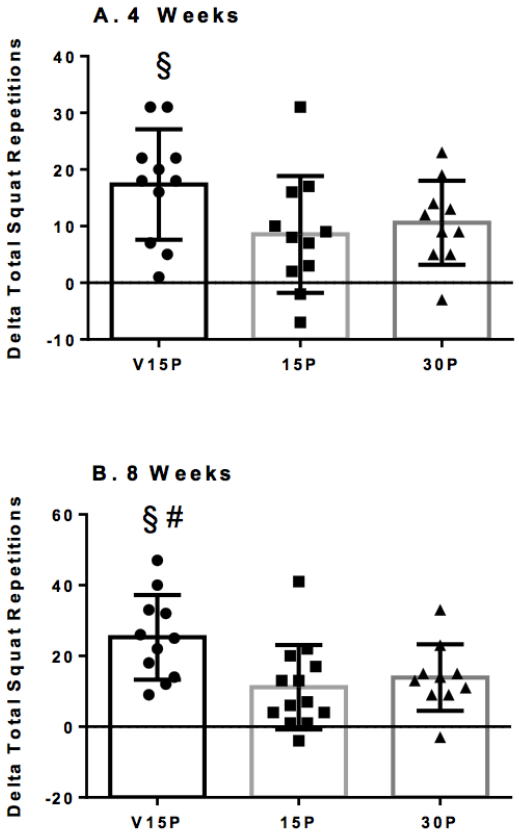
A significant group x time interaction (Figure 2, $p = 0.02$) and time effect ($p < 0.001$) was identified for total squat repetitions. Individual pairwise comparisons revealed that V15P experienced significantly greater increases when compared to 15P (95% CI: 5.0, 23.2 reps, $p = 0.004$) and 30P (95% CI: 1.5, 21.2 reps, $p = 0.03$). A significant group x time interaction (Figure 3, $p = 0.03$) and time effect ($p = 0.003$) was identified for average vertical jump power after being normalized to body mass. Individual pairwise comparisons revealed that the increases in V15P were significantly greater than 30P (95% CI: -2.3, 291 watts/kg, $p = 0.05$) and tended to be greater when compared to 15P (95% CI: -11.0, 259 watts/kg, $p = 0.07$). Vertical jump height exhibited a trend for the group x time interaction (Figure 4, $p = 0.06$). Main effects for time were significant ($p = 0.01$) while the main effect for group was not significant ($p = 0.82$). Separate pairwise comparisons of the observed changes in vertical jump height between V15P and 15P (95% CI: 0.39, 13.8 cm, $p = 0.04$) and V15P and 30P (95% CI: 0.31, 15.3 cm, $p = 0.04$) were significant while changes between 15P and 30P (95% CI: -6.4, 7.8 cm, $p = 0.84$) were not. The group x time interaction for squat 1RM normalized to body mass (Figure 5) was not different ($p = 0.14$), but the main effect for time exhibited a significant change ($p < 0.001$). Separate pairwise comparisons of the observed changes in relative squat 1RM indicated that V15P and 15P were not different (95% CI: -0.02, 0.17 kg/kg, $p = 0.13$) while the changes between V15P and 30P were significantly different, favoring V15P (95% CI: -0.00, 0.22 kg/kg, $p = 0.05$). Significant time effects were observed for relative bench press ($p < 0.001$), bench press total repetitions ($p < 0.001$), average power produced during the best set of vertical jumps ($p < 0.001$), and the peak power produced during the best set of vertical jumps ($p = 0.007$). No other significant effects were observed (Table 4 and Supplementary Table 4).

Table 4. Performance Variables

Variables	N	Visit 2 (Week 0)	Visit 3 (Week 4)	Visit 4 (Week 8)		4-Week	8-Week
Relative Vertical Jump Average Power (watts/kg)							
V15P	11	15.2 ± 2.5	15.7 ± 2.1	17.3 ± 2.9†§#	Group	0.49	0.46
15P	14	16.3 ± 1.9	16.1 ± 1.7	16.7 ± 1.7	Time	0.25	0.003
30P	10	15.2 ± 1.6	15.6 ± 1.4	15.5 ± 1.9†	G x T	0.32	0.03
Relative Bench Press Average Power (watts/kg)							
V15P	11	4.41 ± 1.19	4.53 ± 1.24	4.48 ± 1.05	Group	0.30	0.38
15P	14	4.60 ± 0.76	4.90 ± 1.12	4.69 ± 0.90	Time	0.23	0.29
30P	10	4.11 ± 0.81	4.20 ± 0.79	4.33 ± 0.74†	G x T	0.81	0.70
Relative Bench Press 1RM (kg/kg)							
V15P	11	1.03 ± 0.23	1.08 ± 0.22	1.14 ± 0.22†	Group	0.92	0.88
15P	14	0.99 ± 0.15	1.06 ± 0.17	1.07 ± 0.18†	Time	<0.001	<0.001
30P	10	0.99 ± 0.22	1.05 ± 0.23	1.10 ± 0.24†	G x T	0.66	0.48
Relative Squat 1RM (kg/kg)							
V15P	11	0.99 ± 0.30	1.17 ± 0.23	1.32 ± 0.24†#	Group	0.84	0.74
15P	14	0.95 ± 0.22	1.08 ± 0.25	1.20 ± 0.26†	Time	<0.001	<0.001
30P	10	0.98 ± 0.33	1.12 ± 0.32	1.20 ± 0.34†	G x T	0.48	0.14
Bench Press Total Repetitions							
V15P	11	28.4 ± 7.7	33.5 ± 7.9	35.7 ± 8.6†	Group	0.95	0.99
15P	14	29.0 ± 7.1	32.7 ± 6.7	35.4 ± 7.5†	Time	<0.001	<0.001
30P	10	27.2 ± 6.6	33.1 ± 6.0	37.3 ± 6.6†	G x T	0.66	0.52
Squat Total Repetitions							
V15P	11	24.9 ± 9.4	42.3 ± 6.1†§	50.2 ± 7.4†§#	Group	0.67	0.49
15P	14	30.5 ± 12.1	37.7 ± 19.2	42.5 ± 20.8†	Time	<0.001	<0.001
30P	10	25.0 ± 6.8	35.6 ± 6.6†	38.9 ± 8.5†	G x T	0.04	0.02

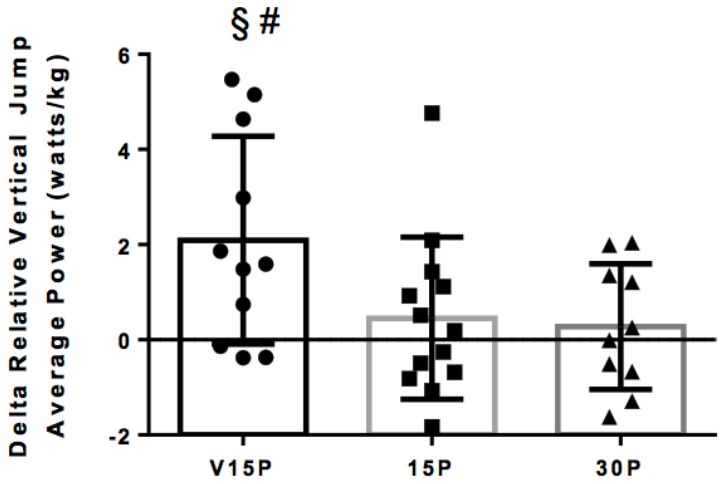
† = Visit 3 different from visit 2 ($p<0.05$); § = Different than 15P ($p<0.05$); # = Different than 30P.

Figure 2. Change in Squat Total Repetitions



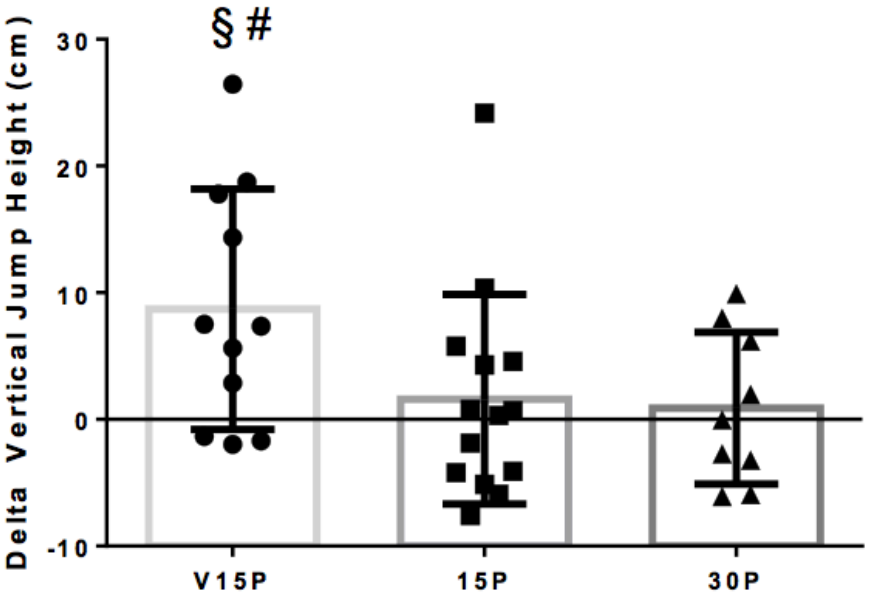
Change in Squat Total Repetitions. Subpanel A depicts delta values after 4 weeks of supplementation. Subpanel B depicts delta values after 8 weeks of supplementation. § = Different than 15P ($p < 0.05$); # = Different than 30P ($p < 0.05$)

Figure 3. Change in Relative Vertical Jump Average Power After 8 Weeks



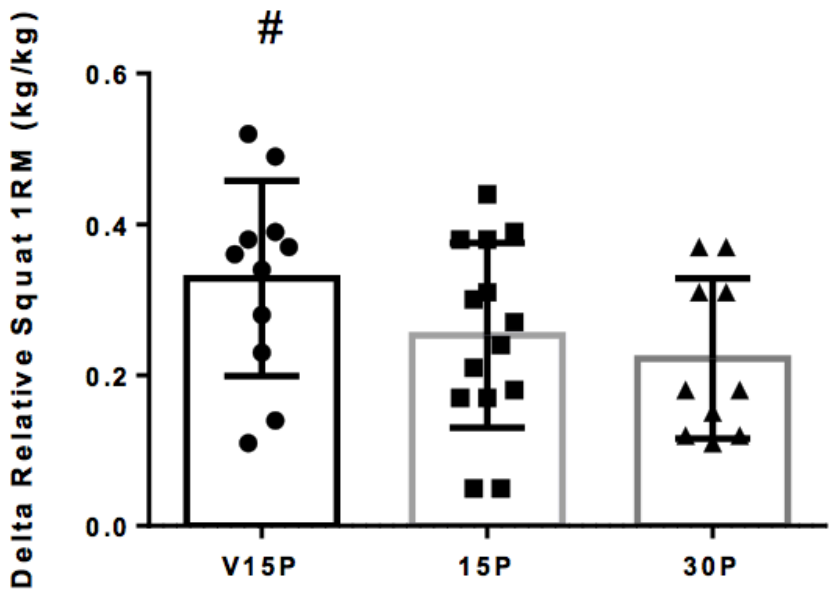
Change in Relative Vertical Jump Average Power After 8 Weeks. § = Different than 15P ($p < 0.05$); # = Different than 30P ($p < 0.05$).

Figure 4. Change in Vertical Jump Height After 8 weeks



Change in Vertical Jump Height After 8 weeks. § = Different than 15P ($p < 0.05$); # = Different than 30P ($p < 0.05$).

Figure 5. Change in Relative Squat 1RM After 8 Weeks



Change in Relative Squat 1RM After 8 Weeks. # = Different than 30P.

Metabolic Markers and Protein Metabolism

Serum levels of glucose and insulin were measured and used to calculate the Homeostatic Model Assessment of Insulin Resistance (HOMA-IR) and beta cell dysfunction (HOMA-B) values. No significant group x time interaction effects were identified for plasma glucose (p = 0.65), insulin (p = 0.54), HOMA-IR (p = 0.66), or HOMA-B (p = 0.38). A significant main effect of time (p = 0.03) for glucose was identified when comparing week 0 and week 4 (Table 5).

No significant group x time interactions were identified for whole-body protein synthesis (p = 0.47) or protein breakdown (p = 0.36) while the group x time interaction for net protein status tended to be significant (p = 0.08). When statistical analysis was completed using only data through 4 weeks, a significant group x time interaction for net protein balance (p = 0.014) was observed. To account for group differences observed at baseline, separate ANCOVA analysis was completed for both the 4-week and 8-week data. The 4-week ANCOVA analysis revealed statistically significant outcomes for net protein balance data (p = 0.005) with no differences for protein synthesis (p = 0.27) or protein breakdown (p = 0.16). Pairwise comparisons of 4-week net protein balance revealed that V15P had higher net protein balance than 15P and 30P (p = 0.05). Alternatively, protein metabolism data over the entire 8-week period did not reveal any statistically significant outcomes for protein synthesis (p = 0.28), protein breakdown (p = 0.36), or net protein balance (p = 0.51), see Table 5 and Figure 6.

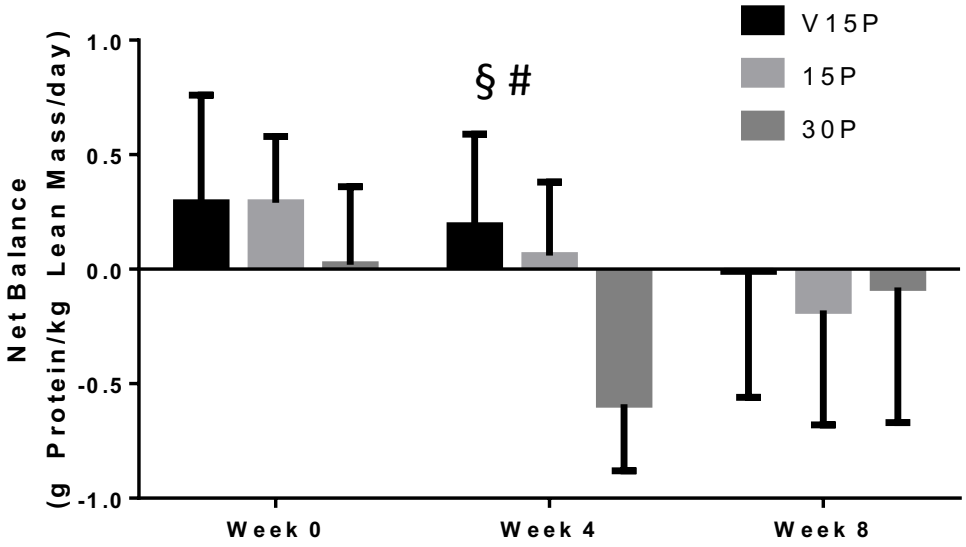
Table 5. Metabolic Markers and Whole-Body (WB) Protein Metabolism Data.

Variables	N	Visit 2 (Week 0)	Visit 3 (Week 4)	Visit 4 (Week 8)		4-Week	8-Week
Glucose (mmol/L)							
V15P	11	5.45 ± 0.54	5.21 ± 0.47	5.26 ± 0.50	Group	0.50	0.58
15P	14	5.21 ± 0.39	5.18 ± 0.43	5.23 ± 0.37	Time	0.03	0.10
30P	10	5.22 ± 0.34	5.04 ± 0.48	5.14 ± 0.50	G x T	0.36	0.65
Insulin (μIU/mL)							
V15P	11	8.6 ± 5.9	10.2 ± 7.6	11.3 ± 7.4	Group	0.56	0.42
15P	14	7.5 ± 3.7	8.8 ± 5.1	8.5 ± 3.6	Time	0.46	0.21
30P	10	7.9 ± 3.2	6.8 ± 2.4	8.2 ± 3.5	G x T	0.39	0.54

HOMA-IR							
V15P	11	2.09 ± 1.45	2.40 ± 1.86	2.64 ± 1.73	Group	0.52	0.40
15P	14	1.76 ± 0.88	2.05 ± 1.21	2.00 ± 0.86	Time	0.60	0.34
30P	10	1.86 ± 0.84	1.58 ± 0.72	1.93 ± 1.01	G x T	0.45	0.66
HOMA-B							
V15P	11	94.2 ± 71.0	119.0 ± 79.1	136.3 ± 90.8	Group	0.75	0.04
15P	14	90.7 ± 48.7	105.8 ± 58.8	100.9 ± 46.2	Time	0.11	0.04
30P	10	91.0 ± 29.6	88.1 ± 9.5	102.2 ± 37.8	G x T	0.37	0.38
WB Protein Synthesis (grams Protein/kg Lean Mass/day)							
V15P	5	0.31 ± 0.34	0.48 ± 0.27	0.37 ± 0.64	Group	0.22	0.09
15P	4	0.42 ± 0.45	0.07 ± 0.58	-0.04 ± 0.35	Time	0.24	0.37
30P	6	0.74 ± 0.29	0.51 ± 0.38	0.58 ± 0.36	G x T	0.18	0.47
WB Protein Breakdown (grams Protein/kg Lean Mass/day)							
V15P	5	0.01 ± 0.47	0.29 ± 0.46	0.37 ± 0.96	Group	0.005	0.05
15P	4	0.13 ± 0.44	0.01 ± 0.67	0.15 ± 0.46	Time	0.14	0.49
30P	6	0.72 ± 0.17*	1.10 ± 0.36	0.67 ± 0.69	G x T	0.22	0.36

* = Different at baseline.

Figure 6. Whole-Body Net Protein Balance



Whole-Body Net Protein Balance. § = Different than 15P ($p<0.05$); # = Different than 30P.

Dietary Intake

Compliance was reported as 90% in completing dietary records and following the supplementation regimen. All dietary intake data can be found in table 6. Significant group x time interaction effects were identified for absolute (p = 0.05) and normalized energy intake (p = 0.03). Follow-up pairwise comparisons using 95% confidence intervals on the observed changes did not reveal any significant differences between separate group comparisons. To further evaluate the potential for group differences, ANCOVA was employed using baseline energy intake as the covariate and the differences were determined to be non-significant (ANCOVA, p = 0.19). Significant group x time interaction effects were identified for absolute (p = 0.04) and normalized carbohydrate intake (p = 0.02). Follow-up pairwise comparisons using 95% confidence intervals on the observed changes revealed that V15P increased their normalized carbohydrate intake more than 15P (95% CI: 9.6, 156.1, p = 0.03) and tended to report higher values when compared to the 30P group (95% CI: -7.9, 146.6, p = 0.08). ANCOVA analysis using baseline carbohydrate intake as the covariate confirmed V15P increased their carbohydrate intake (p =

0.01). Normalized fat intake tended (p = 0.09) to be different between groups with V15P eating more dietary fat over the study protocol while 30P consumed less dietary fat. No group x time interactions were identified for absolute (p = 0.82) and normalized (p = 0.60) protein intake or absolute fat intake (p = 0.16).

Table 6. Dietary Intake.

Variables	N	Visit 2 (Week 0)	Visit 3 (Week 4)	Visit 4 (Week 8)		4-Week	8-Week
Energy Intake (kcals/day)							
V15P	11	1588 ± 385	1808 ± 351	1926 ± 360†	Group	0.07	0.75
15P	14	1972 ± 369*	1850 ± 429	1868 ± 401	Time	0.60	0.88
30P	10	1945 ± 317	1947 ± 510	1703 ± 339	G x T	0.11	0.05
Carbohydrate Intake (grams/day)							
V15P	11	174 ± 26	199 ± 38	221 ± 55†	Group	0.07	0.36
15P	14	214 ± 64	191 ± 70	178 ± 60	Time	0.84	0.92
30P	10	172 ± 77	165 ± 66	149 ± 78	G x T	0.23	0.03
Fat Intake (grams/day)							
V15P	11	59.4 ± 23.9	74.9 ± 21.6	82.6 ± 26.2†	Group	0.07	0.71
15P	14	78.4 ± 20.9	78.5 ± 24.6	78.2 ± 26.7	Time	0.18	0.48
30P	10	85.5 ± 30.8	89.2 ± 51.1	74.4 ± 21.2	G x T	0.42	0.15
Protein Intake (grams/day)							
V15P	11	86 ± 37	85 ± 29	95 ± 27	Group	0.21	0.26
15P	14	113 ± 27	108 ± 38	110 ± 30	Time	0.58	0.90
30P	10	108 ± 24	105 ± 24	100 ± 39	G x T	0.92	0.84
Normalized Energy Intake (kcals/kg/day)							
V15P	11	18.1 ± 4.6	20.8 ± 5.1	22.1 ± 5.1	Group	0.09	0.50
15P	14	19.7 ± 5.0	18.3 ± 5.4	18.4 ± 5.1	Time	0.54	0.71
30P	10	22.6 ± 6.6	22.7 ± 8.5	18.9 ± 3.3	G x T	0.11	0.03
Normalized Carbohydrate Intake (g/kg/day)							
V15P	11	1.98 ± 0.24	2.28 ± 0.53	2.54 ± 0.71	Group	0.79	0.40
15P	14	2.17 ± 0.82	1.89 ± 0.79	1.76 ± 0.69	Time	0.87	0.81
30P	10	1.93 ± 0.92	1.84 ± 0.78	1.60 ± 0.71	G x T	0.16	0.03
Normalized Fat Intake (g/kg/day)							
V15P	11	0.68 ± 0.28	0.86 ± 0.27	0.96 ± 0.39	Group	0.23	0.38
15P	14	0.77 ± 0.21	0.77 ± 0.25	0.77 ± 0.29	Time	0.17	0.45
30P	10	1.02 ± 0.48	1.07 ± 0.71	0.85 ± 0.30	G x T	0.39	0.09
Normalized Protein Intake (g/kg/day)							
V15P	11	0.97 ± 0.45	0.97 ± 0.32	1.08 ± 0.27	Group	0.36	0.53
15P	14	1.12 ± 0.30	1.06 ± 0.38	1.09 ± 0.36	Time	0.41	0.78
30P	10	1.25 ± 0.40	1.21 ± 0.35	1.11 ± 0.40	G x T	0.85	0.59

* = Different at baseline ($p<0.05$); † = Different from visit 2 ($p<0.05$).

Visual Analog Scales and Perceived Recovery

Table 7 illustrates changes observed in perceived recovery and visual analog scales representing energy, willingness to exercise, soreness, and sleep quality after 0, 4, and 8 weeks of supplementation. Aside from a significant ($p<0.05$) increase in soreness in V15P at 4 weeks, no significant group x time interactions were identified for any of measured visual analog scales. Additionally, only soreness revealed a significant main effect for time as all groups experienced similar increases from week 0 week 8. No significant interaction or main effects were identified for perceived recovery.

Table 7. Perceived Recovery and Visual Analog Scales (VAS).

Variables	N	Visit 2 (Week 0)	Visit 3 (Week 4)	Visit 4 (Week 8)		4-Week	8-Week
Perceived Recovery Scale							
V15P	11	7.4 ± 2.2	8.3 ± 0.9	7.5 ± 2.2	Group	0.74	0.62
15P	14	7.6 ± 1.6	7.2 ± 1.9	7.6 ± 1.7	Time	0.18	0.29
30P	10	7.3 ± 1.8	8.2 ± 1.2	8.5 ± 0.9	G x T	0.16	0.18
Energy VAS							
V15P	11	6.7 ± 1.6	6.7 ± 1.1	6.6 ± 1.7	Group	0.72	0.69
15P	14	6.3 ± 1.5	6.6 ± 1.8	6.9 ± 1.3	Time	0.31	0.60
30P	10	5.9 ± 1.8	6.5 ± 1.9	6.2 ± 1.9	G x T	0.62	0.76
Willingness to Exercise VAS							
V15P	11	7.8 ± 1.6	7.5 ± 1.1	7.4 ± 1.4	Group	0.47	0.63
15P	14	6.7 ± 1.6	7.2 ± 1.5	7.3 ± 1.6	Time	0.38	0.79
30P	10	7.1 ± 1.7	7.4 ± 1.7	7.3 ± 2.2	G x T	0.20	0.50
Soreness VAS							
V15P	11	1.39 ± 1.12	3.66 ± 2.52†	2.61 ± 2.59	Group	0.11	0.13
15P	14	2.53 ± 1.94	3.69 ± 2.58	3.20 ± 2.62	Time	0.005	0.005
30P	10	1.32 ± 0.58	2.25 ± 2.32	1.78 ± 1.38	G x T	0.50	0.77
Sleep Quality VAS							
V15P	11	5.66 ± 1.74	6.50 ± 1.68	5.95 ± 1.86	Group	0.49	0.80
15P	14	5.26 ± 1.62	6.14 ± 2.25	5.96 ± 2.26	Time	0.11	0.23
30P	10	6.39 ± 1.04	6.32 ± 0.89	5.71 ± 1.45	G x T	0.44	0.51

† = Visit 3 different from visit 2 ($p<0.05$)

Clinical Safety

All whole blood cell counts and clinical chemistry variables are outlined in Supplementary data Table 2. For all data, no significant group x time interactions were revealed for any of the measured variables with the exception of creatinine ($p = 0.02$) and aspartate aminotransferase ($p = 0.05$), while trends were noted for VLDL Cholesterol ($p = 0.08$) and hemoglobin ($p = 0.08$). All changes, however, remained within clinical accepted normative values and were deemed to be clinically insignificant.

Supplementary Data Table 2. Serum and Whole Blood Metabolic and Hematological Markers.

Variables	N	Visit 2 (Week 0)	Visit 4 (Week 8)		p-value
White Blood Cell Count					
V15P	11	5.66 ± 1.23	5.86 ± 1.00	Group	0.27
15P	14	6.17 ± 2.10	6.59 ± 1.85	Time	0.22
30P	10	5.37 ± 1.22	5.61 ± 0.98	G x T	0.92
Red Blood Cell Count					
V15P	11	5.18 ± 0.51	5.12 ± 0.40	Group	0.85
15P	14	5.05 ± 0.27	5.10 ± 0.31	Time	0.32
30P	10	5.16 ± 0.23	5.08 ± 0.23	G x T	0.11
Hemoglobin (g/dL)					
V15P	11	15.7 ± 1.15	15.58 ± 1.01	Group	0.90
15P	14	15.6 ± 0.82	15.9 ± 0.79	Time	0.92
30P	10	15.7 ± 1.12	15.5 ± 1.21	G x T	0.08
Hematocrit (%)					
V15P	11	44.8 ± 2.5	43.8 ± 2.2	Group	0.82
15P	14	44.8 ± 2.1	44.9 ± 2.0	Time	0.02
30P	10	45.2 ± 2.4	44.0 ± 2.7	G x T	0.10
Blood Urea Nitrogen (mg/dL)					
V15P	11	16.1 ± 3.7	17.4 ± 3.5	Group	0.83
15P	14	15.2 ± 3.0	17.2 ± 3.9	Time	0.06
30P	10	15.8 ± 4.8	15.8 ± 4.0	G x T	0.36

Creatinine (mg/dL)					
V15P	11	1.06 ± 0.10	1.02 ± 0.10	Group	0.75
15P	14	1.01 ± 0.14	1.04 ± 0.13 #	Time	0.02
30P	10	1.05 ± 0.22	0.94 ± 0.17 †	G x T	0.02
BUN: Creatinine					
V15P	11	15.2 ± 3.1	17.1 ± 2.5	Group	0.92
15P	14	15.3 ± 3.5	16.8 ± 4.5	Time	0.003
30P	10	15.0 ± 2.9	17.0 ± 3.7	G x T	0.92
Sodium (mEq/L)					
V15P	11	139.9 ± 1.4	139.5 ± 1.2	Group	0.11
15P	14	140.7 ± 1.4	139.5 ± 1.7	Time	0.01
30P	10	141.3 ± 1.6	140.3 ± 1.4	G x T	0.52
Potassium (mEq/L)					
V15P	11	4.46 ± 0.23	4.37 ± 0.22	Group	0.29
15P	14	4.30 ± 0.28	4.26 ± 0.19	Time	0.14
30P	10	4.34 ± 0.29	4.30 ± 0.18	G x T	0.87
Chloride (mEq/L)					
V15P	11	102.5 ± 1.5	101.9 ± 1.9	Group	0.52
15P	14	102.6 ± 2.6	101.0 ± 2.6	Time	0.02
30P	10	102.9 ± 2.6	102.6 ± 1.8	G x T	0.25
Carbon Dioxide (mEq/L)					
V15P	11	23.6 ± 2.2	22.9 ± 2.0	Group	0.82
15P	14	23.8 ± 1.5	23.1 ± 1.5	Time	0.01
30P	10	23.6 ± 1.3	22.6 ± 1.1	G x T	0.88
Calcium (mg/dL)					
V15P	11	9.50 ± 0.17	9.46 ± 0.26	Group	0.60
15P	14	9.59 ± 0.30	9.53 ± 0.29	Time	0.08
30P	10	9.58 ± 0.43	9.37 ± 0.20	G x T	0.44
Total Protein (g/dL)					
V15P	11	7.06 ± 0.27	7.06 ± 0.26	Group	0.48
15P	14	7.06 ± 0.38	7.12 ± 0.41	Time	0.70
30P	10	6.97 ± 0.57	6.86 ± 0.42	G x T	0.45
Albumin (g/dL)					
V15P	11	4.55 ± 0.20	4.56 ± 0.22	Group	0.29
15P	14	4.66 ± 0.30	4.74 ± 0.29	Time	0.92
30P	10	4.73 ± 0.34	4.62 ± 0.23	G x T	0.20
Globulin (g/dL)					
V15P	11	2.52 ± 0.22	2.49 ± 0.20	Group	0.05
15P	14	2.40 ± 0.29	2.38 ± 0.23	Time	0.76
30P	10	2.24 ± 0.37	2.24 ± 0.35	G x T	0.98
Albumin: Globulin					
V15P	11	1.83 ± 0.17	1.84 ± 0.21	Group	0.01
15P	14	1.97 ± 0.29	2.02 ± 0.23	Time	0.91
30P	10	2.16 ± 0.35	2.12 ± 0.38	G x T	0.82
Bilirubin (g/dL)					
V15P	11	0.65 ± 0.33	0.63 ± 0.26	Group	0.51
15P	14	0.66 ± 0.33	0.66 ± 0.43	Time	0.38
30P	10	0.57 ± 0.18	0.48 ± 0.18	G x T	0.57
Alkaline Phosphatase (IU/L)					
V15P	11	71.6 ± 15.4	74.3 ± 16.0	Group	0.79
15P	14	69.6 ± 20.6	70.5 ± 20.7	Time	0.02
30P	10	65.2 ± 15.5	70.0 ± 19.1	G x T	0.36
AST (U/L)					
V15P	11	27.1 ± 13.5	23.2 ± 11.4	Group	0.97
15P	14	23.8 ± 6.2	25.6 ± 9.0	Time	0.17
30P	10	25.3 ± 8.9	23.1 ± 4.9	G x T	0.05

ALT (U/L)					
V15P	11	24.7 ± 9.9	25.9 ± 12.8	Group	0.81
15P	14	26.1 ± 10.7	27.4 ± 11.7	Time	0.44
30P	10	28.1 ± 9.9	28.5 ± 11.1	G x T	0.95
Total Cholesterol (mg/dL)					
V15P	11	187.6 ± 28.6	190.2 ± 25.6	Group	0.83
15P	14	180.9 ± 29.9	191.2 ± 38.0	Time	0.52
30P	10	196.5 ± 29.3	190.2 ± 25.5	G x T	0.15
Triglycerides (mg/dL)					
V15P	11	118.6 ± 49.1	141.5 ± 63.1	Group	0.34
15P	14	109.3 ± 44.7	99.0 ± 46.3	Time	0.88
30P	10	111.5 ± 43.0	102.0 ± 53.1	G x T	0.08
HDL Cholesterol (mg/dL)					
V15P	11	45.6 ± 10.5	45.6 ± 9.9	Group	0.06
15P	14	51.4 ± 7.5	53.1 ± 8.8	Time	0.89
30P	10	53.7 ± 4.3	52.4 ± 5.1	G x T	0.32
VLDL Cholesterol (mg/dL)					
V15P	11	23.7 ± 9.8	28.3 ± 12.6	Group	0.34
15P	14	21.9 ± 8.9	19.8 ± 9.3	Time	0.93
30P	10	22.4 ± 8.7	20.3 ± 10.6	G x T	0.08
LDL Cholesterol (mg/dL)					
V15P	11	118.2 ± 24.9	116.3 ± 18.9	Group	0.85
15P	14	107.6 ± 26.0	118.4 ± 39.2	Time	0.56
30P	10	120.4 ± 26.1	117.5 ± 26.3	G x T	0.17

† = Different from visit 2 ($p<0.05$); # = Different than 30P.

Discussion

The primary findings from this investigation indicate that lower-body squat repetitions, vertical jump power production, and vertical jump height increased to a greater extent when a combination of 15 grams of whey protein and a complex of amylopectin and chromium were provided (V15P) in comparison to supplementing with just 15 (15P) or 30 (30P) grams of whey protein, respectively. No changes were observed between groups in any of the body composition outcomes (e.g., fat mass, fat-free mass, percent fat, etc.), but net whole-body protein balance (synthesis – breakdown) was greatest in V15P after four weeks. While these previous findings align strongly with the observed improvement in whole-body protein metabolism, more investigation is needed to determine if improvements in neuromuscular physiology, such as improvements in muscle fiber recruitment or calcium handling, are driving the observed increases in repetitions performed, vertical jump power production, and vertical jump height. Finally, diastolic blood pressure decreased to a greater extent in V15P in comparison to 15P and 30P, but still remained within normal clinical ranges.

Previously, we reported that combining amylopectin + chromium with a six gram dose of whey protein improved the muscle anabolism response to acute resistance exercise beyond that of the protein dose alone (11). Other (albeit limited) research has reported beneficial effects of chromium on body composition during resistance training (47, 48). While these previous findings align strongly with the observed improvement in whole-body protein metabolism, more investigation is needed to determine what improvements in neuromuscular physiology (e.g., improvements in muscle fiber recruitment, calcium handling, etc.) are driving the observed increases in repetitions performed, vertical jump power production, and vertical jump height. Nonetheless, these results have implications for athletes competing in weight-restricted sports and/or in events where additional body mass is a potential liability (e.g. wresting, combat sports, sprinting/running, gymnastics, etc.). Additionally, these data are also promising for healthy aging applications and clinical populations in older, sarcopenic adults who may encounter catabolic stressors such as injury, surgery, illness, or bed rest and may not be optimizing protein quantity, dietary distribution and/or protein quality.

Ziegenfuss and colleagues (11) previously published data that illustrated the ability of a combination of six grams of whey protein and two grams of an amylopectin-chromium complex to stimulate greater fractional rates of muscle protein synthesis in comparison to ingesting just six grams of whey protein. In

this study, both conditions significantly increased plasma concentrations of the essential amino acids, but when compared to the protein-only groups, MPS rates were increased approximately two-fold after the amylopectin + chromium and whey protein combination was ingested. Churchward-Venne et al. (49) has published data to illustrate that adding leucine to a 6.25 gram dose of whey protein resulted in MPS rates similar to values observed when a 25-gram dose of whey protein was consumed at rest. However, when the same nutrient combinations were ingested post-exercise, the 25-gram dose of whey protein outperformed the 6.25 grams of whey protein + leucine combination during the early (1 to 3 hours) post-exercise measurement period (i.e., MPS rates during the final two hours of the five-hour post-exercise measurement window were greater with the 25-gram dose of whey protein). These outcomes largely formed the basis of the current investigation whereby longer-term phenotypic adaptations of strength and body composition were investigated between groups that ingested lower amounts of whey protein (15 grams) with (V15P) and without (15P) additional nutrients as well as a higher dose of whey protein (30P).

While multiple studies have shown that whey protein, which typically contains the highest amount of leucine in comparison to other protein sources, stimulates favorable body composition adaptations (2, 50, 51), the impact of a lower dose of protein with additional nutrients which may support anabolism requires further investigation. In agreement with previous investigations, the present study found significant increases in upper- and lower-body strength in addition to increases in lean and fat-free mass (2) over the course of training and supplementation, however, the observed differences between groups in lean and fat-free mass were not statistically significant. These outcomes refute our initial hypothesis that the combination group (V15P) would perform as good or better than 15P in terms of changes in body composition. Due to the lack of similar studies comparing other nutrient combinations with similar (smaller) doses of whey protein, these results are challenging to interpret fully. Kerksick and investigators (52) previously reported greater increases in fat-free mass when a combination of colostrum protein and additional ingredients including creatine monohydrate were consumed. This study employed a similar resistance training stimulus in previously resistance trained men and women, but the daily dose of protein was much higher ($\geq$60 grams) and creatine is well established for its ability to increase strength and fat-free mass (53, 54). Previous work in humans regarding body composition outcomes and chromium supplementation is mixed and also challenging to interpret. Some of this research suggests favorable improvements in body composition in exercising adults (47, 48, 55) while others have failed to show a difference (16-19). Notably, none of these papers included the addition of protein and each used different resistance training programs and study populations than the present study. While a full mechanistic explaination is still lacking, the previous work by Ziegenfuss et al. (11) demonstrated the ability of the amylopectin-chromium complex plus six grams of whey protein isolate to significantly increase rates of muscle protein synthesis in an acute fashion. Previous research has also shown that chromium potentiates the actions of insulin, augments the insulin signaling pathway, enhances AMPK activity, and up-regulates cellular glucose uptake (12, 13), all factors which may help optimize muscle protein kinetics (21), particularly when combined with leucine and other essential amino acids (22).

The lack of difference in body composition outcomes between our treatment groups may be due to the dose of leucine (i.e. which comprised ~13% of the dose for each group) all subjects ingested during the study. Previous work by Moore (4), Yang (6), and Witard (5) all demonstrate increased (and maximal) rates of MPS when a 20 to 40-gram dose of protein is ingested in comparison to when smaller doses (5 – 10 grams) of various protein sources are ingested. Additionally, other studies have suggested that a leucine dose of at least 1.7-2.5 grams is needed to maximally stimulate rates of MPS (4). Indeed, the whey protein used in this study (BiPRO ELITE: www.biprousa.com/shop/elite-vanilla) is reported to have 2.5 grams of leucine per 23.5 gram serving, which would provide an estimated 1.6 and 3.2 grams of leucine for the 15 and 30 gram protein doses, respectively. It is currently unknown if leucine doses above this amount can stimulate greater improvements in body composition, particularly when combined with other bioactive nutrients.

To our knowledge, this is the first study to examine changes in strength and power in response to resistance training and the combination of amylopectin-chromium + whey protein supplementation. While other studies support the observed increases in strength and related performance metrics in combination with resistance training and protein supplementation (2), none of these studies combined the protein with other micronutrients. In this regard, Kerksick and colleagues (52) demonstrated greater

increases in strength when a combination of protein, creatine, and other nutrients were ingested, but the longer study duration (12 weeks) and higher protein dose (60 grams) makes comparing results from these studies difficult. For these reasons, the observed improvements in squat repetitions, average vertical jump power, and vertical jump height in V15P compared to 15P and 30P are noteworthy. Whole-body net protein balance data from this study also favored V15P after four weeks, but not eight weeks. The early increases in whole-body net protein balance may suggest that V15P facilitates early phase adaptations such as improvements in fiber recruitment, calcium handling, etc. to the resistance training program (57). However, we admonish the changes in protein kinetics could also be the apparent increase in caloric intake observed by the V15P group across the study trial. Caloric intake in V15P was slightly lower than the other two groups (approximately 300 kcals) at baseline but increased to similar levels as the other two groups at week 4 and week 8. Notwithstanding these limitations, results from the present study clearly indicate that V15P results in greater improvements in total squat repetitions, vertical jump average power, and vertical jump height.

Strengths of this study include the use of a randomized, double-blind, positive control design with two active protein groups and matching subjects according to their HOMA-IR and resistance training experience. In addition, the resistance training program used in this study was previously shown to promote improvements in strength and body composition (58). Our main limitation is the dietary intake data, which are outlined in Table 7. In this respect, two key issues should be considered. First, the V15P group reported consuming approximately 220 – 340 more calories at week 4 and 8, respectively, when compared to baseline. The additional calories seemed to come in the form of added carbohydrates and fat. Whether or not these increases were true increases or discrepancies in collection of dietary data are not known, but nonetheless could function as a reason for why the V15P experienced improvements in net protein balance and performance outcomes. Second, the reported energy and macronutrient intake levels are almost certainly under-reported across our entire study despite our weekly contacts with all subjects. While under-reporting is well-documented in the literature (60-62), the reported levels of energy, carbohydrate, and protein intake are well below recommended intake levels, particularly when one considers that main effects were observed for improvements in both body composition and performance parameters (59). Another limitation is that our workouts were not supervised directly, but rather subjects were asked to keep a training log and verify their workouts via signature from their training partner or a gym staff member. Finally, we acknowledge that subjects in 30P ingested twice the volume of protein compared to subjects in V15P and 15P. However, we attempted to minimize any potential bias (which would theoretically favor 30P) by using codified, non-translucent, foil-lined packets for all supplements and requiring subjects to administer their product at home and away from other subjects as well as study investigators.

Conclusions

This study demonstrates that the addition of a patented amylopectin-chromium complex to a 15-gram dose of whey protein increases total squat repetitions, average vertical jump power production, and vertical jump height to a greater extent than when 15 and 30 grams of whey protein are consumed alone, respectively, during eight weeks of resistance training. Additionally, the amylopectin-chromium complex plus 15 grams of whey protein also improved net whole-body protein balance during the first four weeks of training but did not augment changes in body composition.

Media-Friendly Summary

Ingesting protein before and/or after resistance exercise has previously been shown to augment training adaptations (i.e. muscle strength, muscle size, power output, etc). This study found that combining 15 grams of whey protein with a patented amylopectin-chromium complex increased lower-body muscular endurance and power (e.g. squat repetitions to failure, vertical power, vertical jump), but did not augment changes in body composition in comparison to protein alone.

Acknowledgements

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Supplementary Figure. Supplement Facts Label of Amylopectin + Chromium Complex.

Supplement Facts

Serving Size: 5 Capsules (2 grams)
Servings Per Container: 15

	Amount Per Serving	% Daily Value
Chromium (from Picolinate and Histidinate)	1000 mcg	834%
Amylopectin (from waxy maize)	1790 mg	†

† Daily Value not established.

Other ingredients: Dicalcium phosphate, microcrystalline cellulose, gelatin, water, magnesium stearate

Distributed by: Nutrition 21, LLC

*These statements have not been evaluated by the Food and Drug Administration. This product is not intended to diagnose, treat, cure or prevent any disease.

Supplementary Data Table 3. Body Circumference and Composition

Variables	N	Visit 2 (Week 0)	Visit 3 (Week 4)	Visit 4 (Week 8)		4-Week	8-Week
Chest Circumference (cm)							
V15P	11	101.6 ± 10.0	102.4 ± 8.1	102.4 ± 8.9	Group	0.33	0.09
15P	14	106.8 ± 6.7	108.6 ± 7.9	109.8 ± 7.4†	Time	0.14	0.19
30P	10	104.2 ± 11.5	104.9 ± 13.8	104.2 ± 10.0	G x T	0.79	0.54
Arm Circumference (cm)							
V15P	11	32.7 ± 2.7	32.9 ± 3.4	33.0 ± 2.7	Group	0.26	0.20
15P	14	34.6 ± 3.0	35.5 ± 3.2	35.3 ± 2.6	Time	0.02	0.06
30P	10	33.4 ± 3.7	34.5 ± 4.8	34.0 ± 3.2	G x T	0.54	0.84
Mid-Thigh Circumference (cm)							
V15P	11	53.6 ± 5.4	54.4 ± 3.3	53.8 ± 4.3	Group	0.11	0.16
15P	14	57.0 ± 4.2	57.3 ± 3.8	57.4 ± 3.7	Time	0.20	0.39
30P	10	54.4 ± 3.3	55.4 ± 3.6	54.8 ± 1.9	G x T	0.83	0.96
DXA Total Mass (kg)							
V15P	11	90.8 ± 13.5	91.1 ± 13.2	91.3 ± 13.5	Group	0.15	0.14
15P	14	100.5 ± 10.9	101.3 ± 11.5	102.4 ± 11.2†	Time	0.09	0.002
30P	10	91.6 ± 17.8	92.1 ± 17.2	92.5 ± 17.4	G x T	0.87	0.30
DXA Fat Mass (kg)							
V15P	11	24.6 ± 7.8	24.1 ± 7.7	24.3 ± 7.6	Group	0.51	0.47
15P	14	28.8 ± 9.2	28.7 ± 9.6	29.4 ± 9.5	Time	0.16	0.27
30P	10	28.0 ± 11.8	27.9 ± 11.3	27.8 ± 10.8	G x T	0.69	0.41
DXA Lean Mass (kg)							
V15P	11	62.9 ± 8.9	63.8 ± 8.3	63.7 ± 8.4†	Group	0.04	0.04
15P	14	68.1 ± 6.0	69.0 ± 5.5	69.4 ± 5.3†	Time	0.003	<0.001
30P	10	60.4 ± 8.0	61.0 ± 7.6	61.5 ± 8.0†	G x T	0.90	0.81
DXA Android: Gynoid Ratio							
V15P	11	1.41 ± 0.30	1.33 ± 0.29	1.35 ± 0.31	Group	0.30	0.39
15P	14	1.24 ± 0.25	1.26 ± 0.32	1.26 ± 0.33	Time	0.99	0.80
30P	10	1.38 ± 0.21	1.43 ± 0.17	1.37 ± 0.24	G x T	0.07	0.25
DXA Percent Body Fat (%)							
V15P	11	27.8 ± 6.3	27.0 ± 6.2	27.2 ± 5.9	Group	0.55	0.55
15P	14	29.3 ± 7.2	28.8 ± 7.2	29.2 ± 7.0	Time	0.009	0.04
30P	10	30.8 ± 6.9	30.5 ± 6.5	30.3 ± 6.0	G x T	0.58	0.62
DXA Lean: Fat Ratio							
V15P	11	2.77 ± 0.82	2.89 ± 0.87	2.82 ± 0.79	Group	0.58	0.58
15P	14	2.69 ± 1.23	2.75 ± 1.23	2.67 ± 1.17	Time	0.009	0.03
30P	10	2.38 ± 0.66	2.41 ± 0.66	2.41 ± 0.61	G x T	0.32	0.49
DXA Visceral Fat (cm^3)							
V15P	11	1322 ± 885	1318 ± 986	1333 ± 985	Group	0.92	0.93
15P	14	1401 ± 779	1375 ± 883	1360 ± 744	Time	0.29	0.51
30P	10	1542 ± 923	1403 ± 745	1440 ± 768	G x T	0.57	0.84
Bod Pod Percent Body Fat (%)							
V15P	11	22.1 ± 7.5	22.4 ± 6.9	22.7 ± 6.8	Group	0.49	0.56
15P	14	23.6 ± 10.3	23.8 ± 10.6	24.1 ± 10.6	Time	0.87	0.98
30P	10	27.2 ± 9.3	26.8 ± 9.4	26.1 ± 9.0	G x T	0.61	0.28
Body Mass Index (kg/m^2)							
V15P	11	27.8 ± 3.2	27.8 ± 3.1	27.9 ± 3.1	Group	0.19	0.17
15P	14	30.2 ± 3.2	30.5 ± 3.3	30.7 ± 3.2	Time	0.03	0.002
30P	10	28.8 ± 4.0	28.9 ± 3.9	29.1 ± 3.9	G x T	0.48	0.38

† = Different from visit 2 ($p<0.05$).

Supplementary Data Table 4. Performance Variables

Variables	N	Visit 2 (Week 0)	Visit 3 (Week 4)	Visit 4 (Week 8)		4-Week	8-Week
Bench Press 1RM (kg)							
V15P	11	92.1 ± 21.1	96.5 ± 18.9	102.1 ± 19.4	Group	0.33	0.39
15P	14	98.9 ± 17.5	107.0 ± 18.7	109.3 ± 21.0	Time	<0.001	<0.001
30P	10	88.9 ± 18.6	94.8 ± 22.2	99.8 ± 23.9	G x T	0.31	0.54
Bench Press Avg Power-Best Set (watts)							
V15P	11	395 ± 108	406 ± 108	404 ± 103	Group	0.04	0.05
15P	14	461 ± 86	497 ± 132	477 ± 102	Time	0.17	0.20
30P	10	371 ± 89	384 ± 102	398 ± 98	G x T	0.71	0.68
Bench Press Peak Power-Best Set (watts)							
V15P	11	561 ± 172	569 ± 154	576 ± 155	Group	0.03	0.02
15P	14	677 ± 118	730 ± 194	725 ± 153	Time	0.21	0.23
30P	10	543 ± 164	575 ± 157	577 ± 162	G x T	0.74	0.87
Relative Bench Press Peak Power (watts/kg)							
V15P	11	6.25 ± 1.82	6.37 ± 1.81	6.39 ± 1.62	Group	0.25	0.23
15P	14	6.79 ± 1.14	7.21 ± 1.68	7.15 ± 1.53	Time	0.25	0.31
30P	10	5.97 ± 1.35	6.27 ± 1.16	6.24 ± 1.12	G x T	0.86	0.96
Squat 1RM (kg)							
V15P	11	88.8 ± 25.8	105.8 ± 22.7	119.4 ± 24.3	Group	0.59	0.48
15P	14	94.8 ± 21.7	108.9 ± 23.7	121.7 ± 23.8	Time	<0.001	<0.001
30P	10	85.5 ± 19.2	99.1 ± 20.1	106.8 ± 20.5	G x T	0.67	0.21
Vertical Jump Average Power – Best Set (watts)							
V15P	11	1366 ± 287	1428 ± 301	1563 ± 321	Group	0.03	0.04
15P	14	1630 ± 250	1623 ± 213	1703 ± 259	Time	0.12	<0.001
30P	10	1368 ± 195	1419 ± 213	1420 ± 299	G x T	0.37	0.09
Vertical Jump Peak Power – Best Set (watts)							
V15P	11	4579 ± 1220	4935 ± 1449	5705 ± 1915	Group	0.003	0.01
15P	14	6597 ± 1985	6729 ± 2516	7249 ± 2712	Time	0.21	0.007
30P	10	4600 ± 714	5323 ± 1054	5537 ± 1405	G x T	0.74	0.87
Relative Vertical Jump Peak Power (watts/kg)							
V15P	11	51.1 ± 13.8	54.8 ± 14.7	63.9 ± 22.9†	Group	0.08	0.19
15P	14	66.0 ± 19.7	67.4 ± 27.8	71.3 ± 26.9	Time	0.23	0.01
30P	10	52.1 ± 12.3	59.0 ± 12.2	61.2 ± 20.7†	G x T	0.79	0.78

† = Different from visit 2 ($p<0.05$).

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