RESISTANCE TRAINING–INDUCED ELEVATIONS IN MUSCULAR STRENGTH IN TRAINED MEN ARE MAINTAINED AFTER 2 WEEKS OF DETRAINING AND NOT DIFFERENTIALLY AFFECTED BY WHEY PROTEIN SUPPLEMENTATION

PAUL S. HWANG,[1] THOMAS L. ANDRE,[1] SARAH K. MCKINLEY-BARNARD,[2]
FLOR E. MORALES MARROQUÍN,[1] JOSHUA J. GANN,[1] JOON J. SONG,[3] AND DARRYN S. WILLOUGHBY[1]
[1]Department of Health, Human Performance, and Recreation, Exercise and Biochemical Nutrition Laboratory, Baylor University, Waco, Texas; [2]Department of Health, Kinesiology and Sport, University of South Alabama, Mobile, Alabama; and [3]Department of Statistical Science, Baylor University, Waco, Texas

ABSTRACT

Hwang, PS, Andre, TL, McKinley-Barnard, SK, Morales Marroquín, FE, Gann, JJ, Song, JJ, and Willoughby, DS. Resistance training–induced elevations in muscular strength in trained men are maintained after 2 weeks of detraining and not differentially affected by whey protein supplementation. *J Strength Cond Res* 31(4): 869–881, 2017—Resistance training (RT) with nutritional strategies incorporating whey protein intake postexercise can stimulate muscle protein synthesis and elicit hypertrophy. The early phases of training-induced anabolic responses can be attenuated with longer-term training. It is currently unknown if short-term detraining (DT) can restore these blunted anabolic responses during a subsequent retraining (ReT) period. Twenty resistance-trained men (age 20.95 ± 1.23 years; $n = 20$) were randomized into one of 2 groups (PRO or CHO; 25 g) in a double-blind manner. Participants followed a 4-day per week RT program (4-week RT; 2-week DT; 4-week ReT) while consuming their respective supplement only on workout days during RT and ReT, but every day during DT. At baseline, 4 weeks after RT (post-RT), 2 weeks after DT (post–2-week DT), and after 4 weeks of ReT after DT (post-ReT), leg press strength (LPS) was assessed and rectus femoris cross-sectional area and lean mass changes were assessed by ultrasonography and dual-energy x-ray absorptiometry, respectively. A factorial 2 × 4 (group by time) analyses of variance with repeated measures were used with a probability level at ≤0.05. LPS was elevated throughout the 10-week training study ($p = 0.003$) with no decrease in LPS after DT in both groups. Although not statistically significant, both groups retained lean mass after DT. A 2-week period of DT appeared to retain muscular strength in resistance-trained men. Therefore, a short-term period of DT can potentially retain lower-body strength in young resistance-trained men irrespective of supplementing with 25 g of whey protein postexercise.

KEY WORDS muscle mass, lean mass, fat mass, body composition, nutrient timing

INTRODUCTION

Skeletal muscle mass is tightly regulated by the balance between the rates of muscle protein synthesis (MPS) and muscle protein breakdown (MPB) (11). Moreover, it is widely established that 2 important factors mediate muscle mass and function, which includes the synergistic effects of strategic amino acid provision and resistance exercise (11,13). The implementation of successive bouts of resistance training (RT) issues a strong stimulus through which accruing muscular hypertrophic responses can occur during the postexercise recovery period (11,26,28). Nutrient timing is known as the strategic manipulation of nutritional feeding to optimize the benefits presented after exercise to maximize performance. To this respect, variations in nutrient timing are highlighted through the periodization of nutrients based on the amalgamation of both specificities in one's training program and the energy demand required for peak performance. As such, strategic intervention of nutrient timing can enhance work capacity, improve body composition, delay fatigue, assist in postexercise recovery, and bolster the anabolic training responses. Furthermore, through the induction of resistance exercise and proper nutritional strategy (i.e., prefeeding/postfeeding),

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Address correspondence to Dr. Darryn S. Willoughby, Darryn_Willoughby@baylor.edu.

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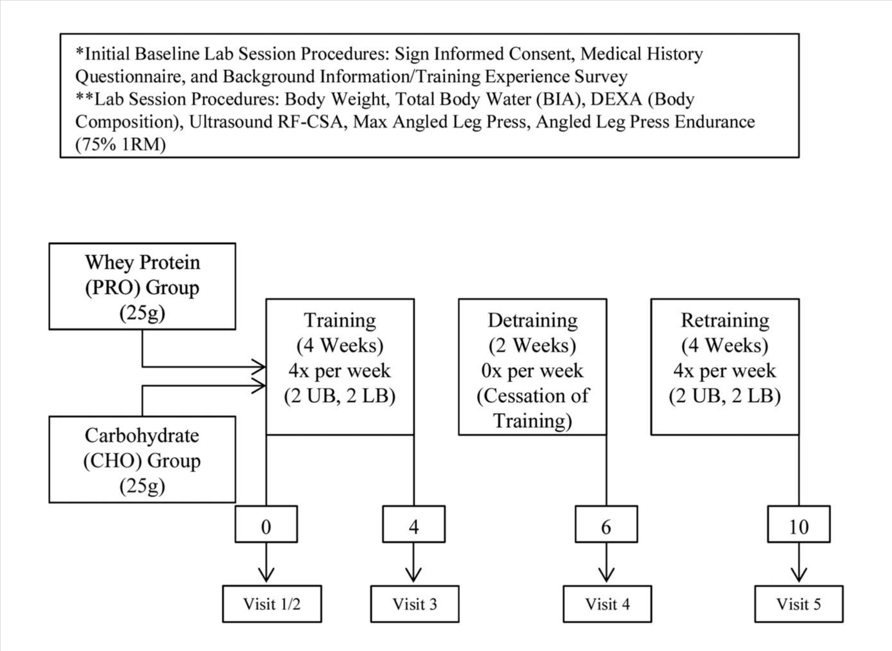

Figure 1. Illustration of the experimental design for testing sessions in the laboratory. Each visit is associated with the particular week of the total 10-week training study. BIA = Bioelectrical Impedance Analysis; DEXA = dual-energy x-ray absorptiometry; RF-CSA = rectus femoris cross-sectional area; 1RM = 1 repetition maximum; UB = upper body; LB = lower body.

favorable elevations in the rate of MPS can generate a positive net protein balance for hypertrophic adaptations (4,11,13). Alongside the acute postexercise MPS response, the integration of adequate protein feeding during the "anabolic window" after resistance exercise may further bolster the stimulation of MPS (4,11,13,30,31).

Interestingly, the presence of RT-induced muscle anabolism and concomitant hypertrophic adaptations is known to occur rapidly during the early phases of exercise training with the attenuation of these responses as time progresses (26–28,38). In other words, the dynamic and malleable nature of skeletal muscle and its ability to respond with hypertrophic adaptations is known to decrease with chronically repeated stimulations (26,27). A review of RT studies presented evidence that the relative percent change within the existing cross-sectional area (CSA) of the thigh muscles has been shown to decrease by 0.06% in the transition from the early phases of training (3 months with a 0.11% increase per day) to a longer-term RT cycle (5–6 months with a 0.05% increase per day) (38).

Recent evidence suggests that the utilization of a short-term cessation of training, otherwise known as detraining (DT), could replete the muscle anabolic adaptation responses to elicit resensitized adaptive responses during successive periods of retraining (ReT) (26,28). Furthermore, the cessation of regular physical training could potentially reduce athletic performance and invoke conditions of progressive atrophy (23,26,27). To this respect, DT is defined as the "partial or complete loss of training-induced anatomical, physiological, and performance adaptations as a consequence of training reduction or cessation" (23). There are various outside variables, such as illness, injury, and a lack of proper recovery between bouts of resistance exercise, which can further elicit the state of DT. Therefore, strategically integrating short-term reductions in training with proper tapering strategies may assist in eliminating negative consequences associated with chronic training while maintaining the positively gained physiological adaptations (15,23,26,27). Presently, there is a considerable amount of research presenting evidence of the efficacy behind DT periods on muscle mass, strength, and power output (1,10,15–18,27,33,35,37).

Lovell et al. (18) observed that strength, maximum force, and rate of force development (RFD) within sedentary yet healthy older men were decreased after 4 weeks of DT; however, these values remained higher than the pretraining levels (strength training and maximum force) besides the RFD. They also mentioned that the short period of DT (4 weeks) still reduced neuromuscular variables, maximum force production, and strength gains significantly in comparison with the 16-week training cycle of resistance exercise. Tokmakidis et al. (37) observed that even in the midst of significant decreases in strength and muscle mass after a period of DT (12 weeks), older adults who performed a 12-week training program of moderate to high intensity were able to still maintain a higher level of maximum knee extension and flexion strength and CSA of the active muscles in comparison with pretraining levels. Kraemer et al. (16) observed that 6 weeks of DT negatively affected anaerobic power and peak isometric torque production of the elbow extensor and flexor muscles within resistance-trained men. However, this period of DT did not significantly reduce both upper-body (UB) and lower-body (LB) dynamic muscular strength outcomes. Another study by Ogasawara et al. (27) observed similar improvements in muscle CSA and strength in bench press exercise training between a periodic (PTR) RT group (3 cycles of 6-week training and 3 weeks of DT) and a continuous (CTR) RT group (train over 24-week period) within young untrained men. The PTR group had significantly higher increases in

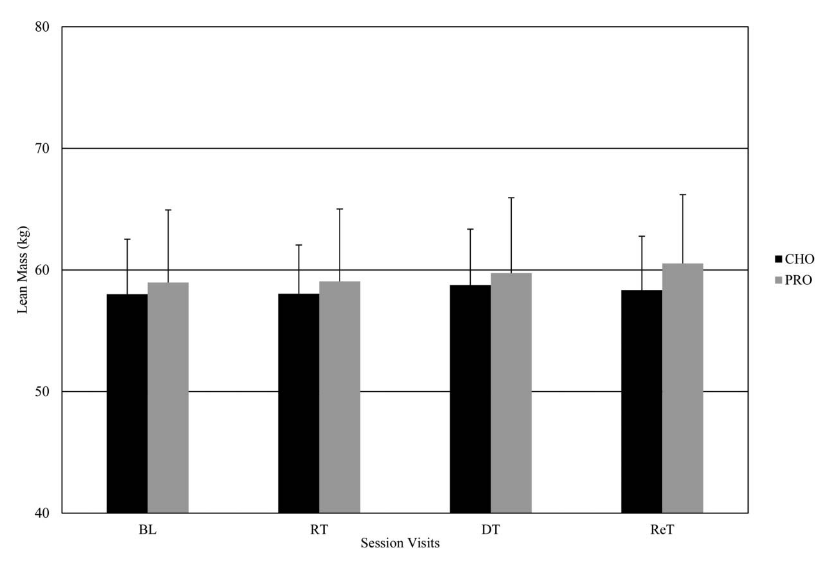

Figure 2. Total lean mass changes. kg = kilograms; session visits: BL = baseline; RT = after 4 weeks of weight training; DT = after 2 weeks of detraining; ReT = after 4 weeks of retraining. No statistically significant differences were found between groups and session visits ($p > 0.05$).

muscle CSA and strength during the second full 3-week DT/6-week training cycle compared with the overall similar training period of the CTR group. This finding may then suggest attenuations in the rate of strength and hypertrophy over chronic training periods. Moreover, the relative improvements in the rate of muscle CSA and strength within the PTR group may also suggest benefits of DT for maintaining and elevating strength and accrued muscle mass. In lieu of these aforementioned studies, it is wise to note that there are no experimental studies to date that have explored the effects of short-term DT and subsequent ReT in resistance-trained individuals.

It is widely established that trained individuals with a history of RT can regain force quickly through periods of ReT, which has been commonly associated with the term "muscle memory" (33,35). These prolonged effects may be associated with the previous adaptations gained within the central nervous system. Smith et al. (33) observed that elderly individuals with previous RT experience still retained hypertrophic adaptations with force that was 9–14% higher after 2 years of DT. Additionally, Staron et al. (35) observed that after 30–32 weeks of DT, a group of women were able to regain the strength of a previous 20-week training program with only 6 weeks of ReT. By contrast, Henwood and Taaffe (15) observed that older adults (65–84 years) who entered into a 24-week DT period with subsequent 24 weeks of ReT did not gain significantly higher values for muscle strength, power, and movement velocity compared with the pretraining values. Nevertheless, these researchers still noted that the relative gains in muscle function and functional performance were preserved during the sessions of DT in contrast to the modest loss in muscle strength and power. In summary, all these studies reinforce how the central nervous system activity and physiological adaptations gained with ReT sessions can assist in regaining atrophied muscle or lost force production due to periods of DT.

Although the synergistic addition of mechanical overload and proper nutritional supplementation can upregulate processes to elicit hypertrophic adaptations, the integration of short-term DT may allow for the repletion of the robust anabolic processes underlying MPS while also retaining previous anabolic gains (26–28). Furthermore, investigations into the effects of short-term DT and subsequent ReT with an additional emphasis on strategic postexercise protein feeding may optimize strength and hypertrophic adaptations within resistance-trained populations. Therefore, the primary purpose of this study was to examine the effects of a 4-week RT program followed by a successive cycle of a short-term DT and subsequent ReT period on body composition and muscle performance within young resistance-trained men. In addition, the secondary purpose of this study was to explore whether there is also a differential additive effect by implementing postexercise whey protein supplementation throughout the training program. We hypothesized that the incorporation of a 2-week DT period would not negatively affect previous gains in muscle strength and mass from 4 weeks of RT, and would also not impede gains in strength and mass in response to a 4-week period of ReT. Moreover, we also hypothesized that the incorporation of whey protein supplementation postexercise would elicit a greater positive adaptation in muscle mass accretion and strength.

METHODS

Experimental Approach to the Problem

The current investigation was a randomized, double-blind, experimental design in which participants were randomized to participate in 2 groups. One group ingested 25 g daily of whey protein and the other 25 g of maltodextrin while also engaging in 4 weeks of RT, followed by 2 weeks of DT, and then 4 weeks of ReT to determine the effects of this experimental protocol on muscle strength and endurance, body composition, and rectus femoris (RF) CSA (Figure 1).

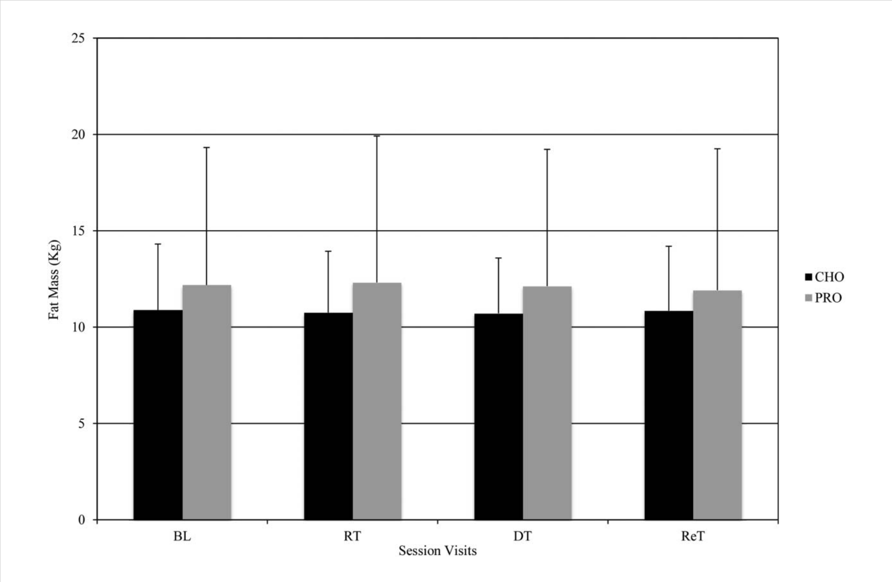

Figure 3. Total fat mass changes. kg = kilograms; session visits: BL = baseline; RT = after 4 weeks of weight training; DT = after 2 weeks of detraining; ReT = after 4 weeks of retraining. No statistically significant differences were found between groups and session visits ($p > 0.05$).

The purpose of the study was to explore if the incorporation of a 2-week period of DT would negatively affect any increases in muscle mass and LB strength acquired from 4 weeks of RT. Additionally, the study sought to determine whether the period of DT would have any effect of muscle mass and strength after a subsequent 4 weeks of ReT. In addition, this study explored whether whey protein or carbohydrate supplementation could differentially affect muscle performance and body composition during this training program.

Subjects

Twenty apparently healthy, resistance-trained (regular, consistent RT [i.e., thrice weekly] for at least 1 year before the onset of the study), men between the ages of 18 and 30 volunteered to serve as participants in this study. Enrollment was open to men of all ethnicities. Only participants considered as low risk for cardiovascular disease and with no contraindications to exercise as outlined by the American College of Sports Medicine (ACSM), and who had not consumed any nutritional supplements (excluding multivitamins) 1 month before the study were allowed to participate. All eligible participants were fully informed of the benefits and risks of this investigation and were asked to provide oral and informed written consent by signing university-approved documents before participation. The approval for this study was granted by the Institutional Review Board for Human Subjects. Additionally, all experimental procedures involved in the study conformed to the ethical consideration of the Helsinki Code.

Procedures

Entry and Familiarization Session. Subjects expressing interest in participating in this study were interviewed on the phone or through e-mail to determine whether they appeared to qualify to participate in this study. Participants believed to meet eligibility criteria were invited to attend an entry or familiarization session. Once reporting to the laboratory, participants were familiarized to the study protocol via a verbal and written explanation outlining the study design and then read and signed a university-approved informed consent document. Participants then completed a medical history questionnaire and underwent a general physical examination to determine whether they further met eligibility criteria. At the conclusion of the familiarization session, participants were given an appointment in which to attend their first testing session. In addition, each participant was instructed to refrain from exercise for 24 hours before each testing session, eat a light breakfast 2 hours before reporting for each testing session, and record their dietary intake for 4 days (including the light breakfast the morning of testing) before each of the 4 testing sessions involved in the study. They were also informed that when they report to the laboratory for their testing sessions (visits 2–5), they would undergo assessments for body composition and muscle performance assessments for the LB involving the angled leg press exercise.

Dietary Analysis. Participants were required to record their dietary intake for 4 consecutive days before each of the 4 testing sessions. The participants' diets were not standardized and participants were asked not to change their dietary habits during the course of the study. The dietary recalls were evaluated with the Food Processor dietary assessment software program (ESHA Research, Salem, OR, USA) to determine the average daily macronutrient consumption of fat, carbohydrate, and protein in the diet for the duration of the study.

Body Composition Testing. At each of the 4 testing sessions, total body mass (kg) was determined on a standard dual beam balance scale (Detecto, Bridgeview, IL, USA). Total body water (TBW) was determined with bioelectrical spectroscopy (ImpediMed Ltd., Pinkenba, QLD, Australia) using a low-energy, high-frequency current (500 μA at a frequency of 50 kHz). Fat mass and fat-free mass was

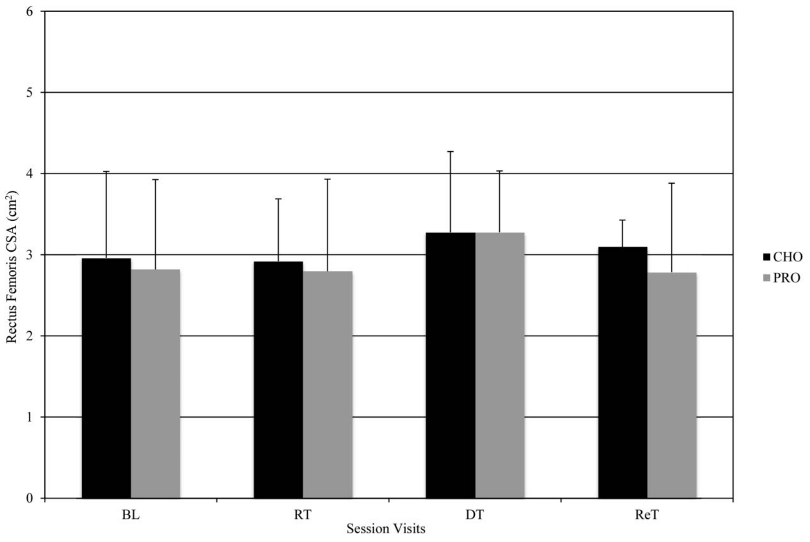

Figure 4. Rectus femoris cross-sectional area (CSA) changes. cm^2 = centimeters squared; session visits: BL = baseline; RT = after 4 weeks of weight training; DT = after 2 weeks of detraining; ReT = after 4 weeks of retraining. No statistically significant differences were found between groups and session visits ($p > 0.05$).

determined using a calibrated dual-energy x-ray absorptiometry ([DEXA] Hologic Discovery Series W, Waltham, MA, USA). Quality control calibration procedures were performed on a spine phantom (Hologic X-CALIBER Model DPA/QDR-1 anthropometric spine phantom) and a density step calibration phantom before each testing session.

Assessments of Rectus Femoris Muscle Mass. An assessment of RF-CSA was performed using ultrasonography (Sonosite M-Turbo, Milwaukee, WI, USA) based on our previously published guidelines (2). Imaging was conducted after participants had rested in this position for 5 minutes to allow for the normalization of fluid shifts. Scanning was performed in the supine position with a rolled-up towel placed in the popliteal fossa to relax the upper thigh. The scanning site was identified as the midpoint of the distance from the greater trochanter to the knee joint line. A 13.5-MHz linear array transducer was placed perpendicular to the long axis of the thigh to obtain a frozen real-time cross-sectional image of the RF muscle to determine CSA. To ensure consistency in measurements at each time point, images of all participants were obtained by the same investigator who was trained in Doppler ultrasound, and had performed these assessments in a previous study (2).

Muscle Strength and Endurance Assessments. To determine muscular strength at each of the 4 testing sessions, participants performed 1 repetition maximum (1RM) tests in accordance with the National Strength and Conditioning Association (NSCA) recommendations on the angled leg press. Participants warmed up by completing 5–10 repetitions at approximately 50% of the estimated 1RM. The participant rested for 1 minute, and then completed 3–5 repetitions at approximately 70% of the estimated 1RM. The weight was increased conservatively, and the participant then attempted to lift the weight for 1 repetition. If the lift was successful, the participant rested for 2 minutes before attempting the next weight increment. This procedure was continued until the participant failed to complete the lift. The 1RM was recorded as the maximum weight that the participant was able to lift for 1 repetition. To assess muscle endurance, using the angled leg press exercises, participants performed as many repetitions as possible with 75% of their 1RM (34).

Resistance Training and Retraining Protocol. Based on our previous studies (39,40), participants completed a periodized 28-day RT program split into 2 upper-extremity and 2 lower-extremity exercise sessions each week. This constituted a total of 16 exercise sessions, with 8 UB and 8 LB exercise sessions. Each exercise session started with a standardized series of stretching exercises. The participants then performed an upper-extremity RT program consisting of 9 exercises (bench press, lat pull-down, shoulder press, seated row, shoulder shrug, chest flys, biceps curl, triceps press down, and abdominal curls) twice per week and also a program consisting of 7 lower-extremity exercises (leg press, back extension, step up, leg curl, leg extension, heel raise, and abdominal crunch) twice per week. Participants performed 3 sets of 10 repetitions at 75% of their 1RM. Rest periods were 2 minutes between exercises and between sets.

Volume Load. Volume load (weight × sets × reps) was set to 3 sets of 10 repetitions at an intensity of 75% of their 1RM for the workout sessions throughout the RT program. Volume load was recorded for each exercise in both UB and LB workouts in both groups.

Detraining Protocol. Immediately after the 28-day RT period, and immediately before the 28-day ReT period, a 14-day DT period occurred in which all participants engaged in no formal RT or structured physical activity. A written form stating to such adherence ascertained compliance. Moreover, participants were also verbally contacted periodically

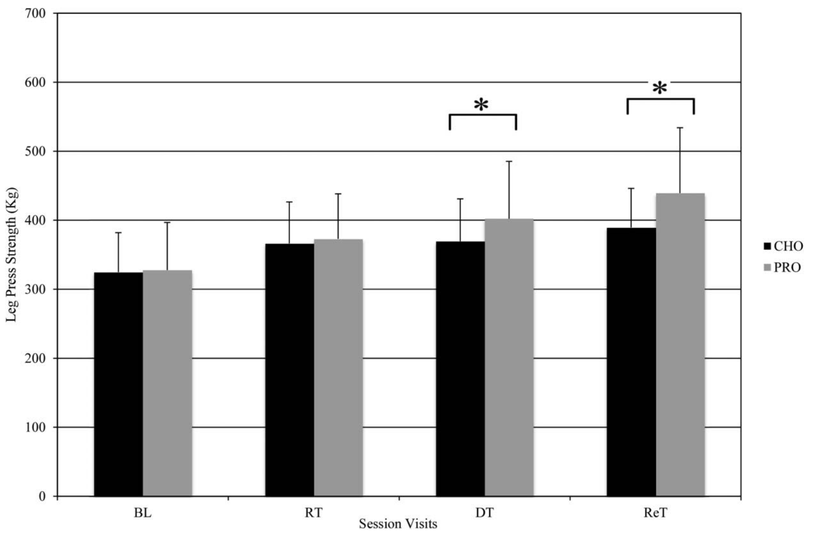

Figure 5. Leg press strength. kg = kilograms; session visits: BL = baseline; RT = after 4 weeks of weight training; DT = after 2 weeks of detraining; ReT = after 4 weeks of retraining. *CHO and PRO both significantly different from baseline ($p \leq 0.05$).

throughout the 14-day period to confirm the adherence to the DT protocol.

Nutrient Supplementation Protocol. Throughout the duration of the RT, DT, and ReT protocol, in a randomized, doubled-blind fashion, participants were assigned to either a carbohydrate (CHO) or whey protein group (PRO). During the RT and ReT periods, immediately after each resistance exercise session, either 25 g of maltodextrin carbohydrate supplement (Pure Karbolyn; Pro Supplements, Inc., Allen, TX, USA) or 25 g of whey protein (PS Whey; Pro Supplements, Inc., Allen, TX, USA) was orally ingested. Neither supplement was ingested on nonexercise days.

However, during the 14-day DT period, the 25 g of each respective supplement was ingested every day in the morning upon waking. Each participant was provided with enough of their respective supplement for the entire duration of the study. A plastic scoop was provided with each supplement that, when completely filled with supplement powder, yielded 25 g. One scoop of supplement was mixed with 12 ounces of water and orally ingested. Participants were required to complete a daily supplement compliance questionnaire to assist them in their compliance, which would also assist research personnel in establishing compliance to the supplementation protocol throughout the course of the study.

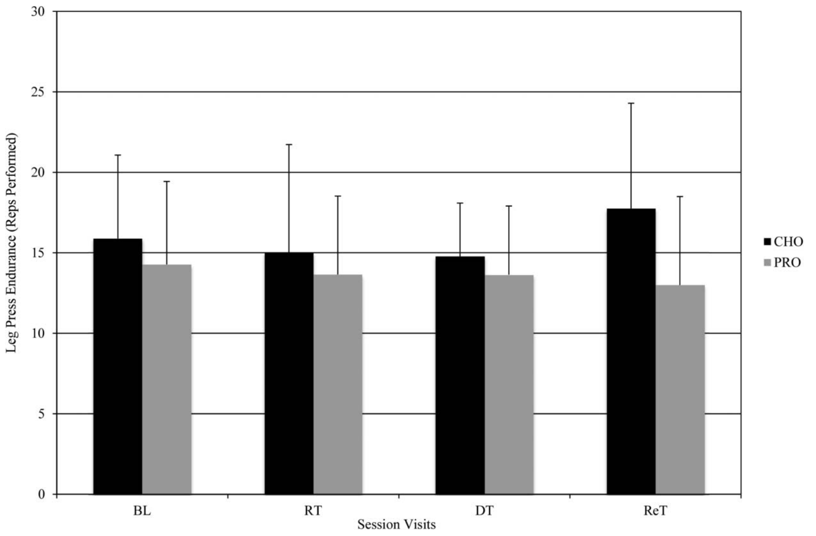

Figure 6. Leg press endurance. kg = kilograms; session visits: BL = baseline; RT = after 4 weeks of weight training; DT = after 2 weeks of detraining; ReT = after 4 weeks of retraining. No statistically significant differences were found between groups and session visits ($p > 0.05$).

Statistical Analyses

An independent *t*-test was performed to determine significant differences in the overall training volume between groups. Moreover, statistical analyses were also performed by using separate 2 × 4 (Group [CHO, PRO] × Test [pretraining, posttraining, post-DT, post-ReT]) factorial analyses of variance (ANOVAs) with repeated measures for all other variables of interest. Further analysis of the main effects was performed by separate 1-way ANOVAs. Significant between-group differences were then determined involving the Tukey's post hoc test. An a priori power calculation showed that 10 participants per group was adequate to detect a significant difference

Table 1. Participant baseline characteristics ($n = 20$).*

Participant baseline characteristics	Mean values ± *SD*
Age (y)	20.95 ± 1.23
Height (in)	70.25 ± 2.62
Body weight (kg)	79.21 ± 9.22
Total body water (kg)	48.13 ± 3.15
Lean mass (kg)	58.53 ± 5.25
Fat mass (kg)	11.60 ± 5.68
Leg press 1RM (kg)	326.47 ± 62.33
Leg press endurance at 75% 1RM (Reps)	15.00 ± 5.10

*in = inches; kg = kilograms; 1RM = 1 repetition maximum.

between groups in the marker of muscle strength in response to RT, given a type I error rate of 0.05 and a power of 0.80. The index of effect size used was partial Eta squared (η^2), which estimated the proportion of variance in the dependent variable that would be explained by the independent variable. Partial Eta-squared effect sizes were determined to be: weak = 0.17, medium = 0.24, strong = 0.51, and very strong = 0.70 (25). All statistical procedures were performed using SPSS 20.0 software (Chicago, IL, USA), and a probability level of ≤ 0.05 was adopted throughout. All data are presented as mean ± *SD*.

RESULTS

Anthropometric Baseline Data

The baseline anthropometric and muscle performance data describing the 20 participants who completed the study are presented in Table 1 and 2. During the course of the study, 3 participants were dropped from the study because of compliance conflicts.

Dietary Analyses

The completed dietary intake forms were used to analyze the average daily caloric and macronutrient consumption, although omitting the additional calories ingested from their respective supplements (Table 3). These results revealed no significant differences for kilocalories, fat, carbohydrate, or protein intake between PRO and CHO groups over the course of the study ($p > 0.05$).

Training Compliance and Volume Load of Training

Three participants were unable to complete every workout session for the 4-week RT and ReT periods. One participant was only able to complete 13 of 16 (93.75%) with the 3 missed sessions coming from the RT period of the total LB workouts because of temporary muscular injury. Another participant was also only able to complete 13 of 16 (93.75%) with the 3 missed sessions coming from the RT period for both the UB and LB workout sessions because of temporary illness. Lastly, one other participant suffered a minor muscular injury and was only able to complete 13 of 16 (93.75%) with the 3 missed sessions coming from the ReT period of the total LB sessions in this training study.

In regard to training volume load, statistical analyses were performed on the training volume load between groups for both the 4-week RT and ReT programs to ascertain if any significant differences were present in the overall UB and LB volume load. There were no significant differences between groups for volume load (defined as repetitions × sets × weight) in both UB and LB cumulative exercise sessions. Mean values ± *SD* for the overall volume load between groups are presented in Table 4.

Table 2. Group-specific participant baseline characteristics.*†

	Mean values ± *SD*		
Participant baseline characteristics	CHO	PRO	p (≤ 0.05)
Sample size (n)	9	11	–
Age (y)	21.00 ± 1.12	20.91 ± 1.38	0.693
Height (in)	70.19 ± 2.76	70.45 ± 2.66	0.638
Body weight (kg)	77.72 ± 7.80	80.45 ± 10.44	0.354
Total body water (kg)	47.5 ± 2.61	48.73 ± 3.72	0.677
Lean mass (kg)	58.0 ± 4.53	59.0 ± 6.02	0.644
Fat mass (kg)	10.89 ± 3.43	12.09 ± 7.26	0.132
Leg press 1RM (kg)	324.82 ± 57.24	327.82 ± 68.96	0.508
Leg press endurance at 75% 1RM (Reps)	15.89 ± 5.18	14.27 ± 5.16	0.878

*in = inches; kg = kilograms; 1RM = 1 repetition maximum.
†Significant differences are investigated by an independent group *t*-test.

TABLE 3. Dietary intake and energy expenditure variables at baseline, after 4 weeks of RT, after 2 weeks of DT, and after 8 weeks of ReT.*†

Variable	Group	Visit BL	Visit RT	Visit DT	Visit ReT
Total calories (kcals·d^{-1})	PRO	1,923.16 (479.60)	2,055.69 (529.82)	2,028.75 (537.91)	1,999.96 (350.45)
	CHO	1,931.97 (410.64)	2,141.25 (595.85)	2,206.22 (483.24)	2,210.54 (562.82)
Protein (g·d^{-1})	PRO	101.70 (23.27)	108.53 (31.14)	106.68 (33.46)	101.25 (17.11)
	CHO	103.53 (35.24)	123.58 (53.97)	117.72 (32.81)	125.14 (40.64)
Carbohydrates (g·d^{-1})	PRO	206.85 (71.22)	222.13 (80.30)	217.79 (85.91)	216.50 (51.31)
	CHO	206.64 (63.01)	210.25 (73.28)	227.80 (50.77)	224.52 (64.13)
Fat (g·d^{-1})	PRO	77.17 (24.80)	89.51 (25.84)	93.33 (25.26)	87.78 (23.55)
	CHO	77.64 (18.16)	81.12 (25.34)	74.51 (24.27)	82.22 (28.23)
TDEE (kcals·d^{-1})	PRO	3,110.17 (170.16)	3,094.30 (160.17)	2,069.20 (109.35)	3,111.44 (164.13)
	CHO	3,037.60 (159.12)	3,035.81 (154.30)	2,032.76 (108.77)	3,046.35 (162.72)

*BL = baseline; RT = after 4 weeks of weight training; DT = after 2 weeks of detraining; ReT = after 4 weeks of retraining.

†All data presented as mean values ± *SD*. No statistically significant differences are found between PRO and CHO groups for total calories, protein, carbohydrates, and fat throughout the study ($p > 0.05$).

Body Composition

It is important to mention that 19 of the 20 participants fully completed body composition assessments to accurately measure both lean and fat mass changes. One participant was unable to perform the DEXA protocol at appropriate time points (after 4 weeks of weight training [RT] and after 2 weeks of DT) because of temporary machine malfunction.

With respect to TBW changes, there was no statistically significant interaction between group and time ($p = 0.999$; partial $\eta^2 = < 0.001$). The main effect of group revealed no statistically significant difference in TBW changes throughout the study ($p = 0.180$; partial $\eta^2 = 0.025$). The main effect of time had no statistically significant differences between time points ($p = 0.897$; partial $\eta^2 = 0.008$).

Lean Mass and Fat Mass Changes

The changes in lean mass and fat mass from baseline to each appropriate time point (after 4 weeks of weight training [RT]; after 2 weeks of DT; after 4 weeks of ReT) are presented in Figures 2 and 3 respectfully. There were no statistically significant interactions between group and time for lean mass ($p = 0.988$; partial $\eta^2 = 0.002$) and fat mass changes ($p = 0.999$; partial $\eta^2 = < 0.001$). The main effect of group revealed no statistically significant differences in lean mass ($p = 0.308$; partial $\eta^2 = 0.015$) and fat mass changes ($p = 0.315$; partial $\eta^2 = 0.014$) throughout the training study. The main effect of time also revealed no statistically significant differences in lean mass ($p = 0.901$; partial $\eta^2 = 0.008$) and fat mass ($p = 1.000$; partial $\eta^2 = <$ 0.001) between time points.

Rectus Femoris Cross-Sectional Area

The changes in RF-CSA from baseline to each appropriate time point (after 4 weeks of weight training [RT]; after 2 weeks of DT; after 4 weeks of ReT) are presented in Figure 4. There was no statistically significant interaction between group and time for CSA changes ($p = 0.966$; partial $\eta^2 =$ 0.004). The main effect of group revealed no statistically significant difference in CSA changes throughout the study ($p = 0.504$; partial $\eta^2 = 0.006$). The main effect of time had no statistically significant differences between time points ($p = 0.491$; partial $\eta^2 = 0.033$).

Leg Press Strength and Endurance

With respect to leg press strength (LPS), changes at baseline and subsequent time points between groups are presented in Figure 5. There was no statistically significant interaction between group and time for LPS ($p = 0.706$; partial

TABLE 4. Overall volume load in UB and LB sessions between groups.*†

Group	Variable (kg)	LB	*p* (LB) (≤0.05)	UB	*p* (UB) (≤0.05)
CHO (*n* = 9)	Volume load	231,251.01 ± 37,540.43	0.548	129,696.88 ± 29,523.69	0.949
PRO (*n* = 11)	Volume load	220,363.01 ± 41,653.30	0.548	130,652.54 ± 34,809.80	0.949

*kg = kilograms; LB = lower body; UB = upper body.

†All data presented as mean values ± *SD*.

$\eta^2 = 0.020$). The main effect of group revealed no statistically significant differences in LPS throughout the study ($p = 0.158$; partial $\eta^2 = 0.182$). The main effect of time demonstrated a statistically significant difference in LPS between time points ($p = 0.003$; partial $\eta^2 = 0.182$). Post hoc analyses revealed that LPS significantly increased at the DT time point (after 2 weeks of DT) compared with baseline ($p = 0.040$). In addition, LPS was significantly greater at the RT time point (after 4 weeks of ReT) compared with baseline ($p = 0.001$).

With respect to leg press endurance (LPE), changes at baseline and subsequent time points between groups are presented in Figure 6. There was no statistically significant interaction between group and time ($p = 0.688$; partial $\eta^2 = 0.021$). The main effect of group did not reveal statistically significant differences throughout the study ($p = 0.068$; partial $\eta^2 = 0.047$). Furthermore, the main effect of time also did not reveal a statistically significant difference in LPE between time points ($p = 0.878$; partial $\eta^2 = 0.010$).

DISCUSSION

The purpose of this study was to examine the effects of a 4-week RT training program followed by a successive cycle of a short-term DT and subsequent 4-week ReT periods on body composition and muscle performance in resistance-trained young men. A secondary purpose of this study was to elucidate whether the supplementation of 25 g of carbohydrate (CHO) or whey protein (PRO) postworkout could provide an additive differential response on body composition and muscle performance. It is widely conceived that skeletal muscle mass is highly regulated by the balance between the rates of MPS and MPB (11). The synergistic addition of mechanistic overload and proper nutritional supplementation over time can culminate into periods of positive net protein balance through which processes of MPS and concomitant hypertrophy adaptations ensue (6,9,11,13,27). However, chronic repetitive muscle contractions can reduce the dynamic anabolic responsiveness of skeletal muscle and attenuate the underlying processes of muscle accretion over time (26). Moreover, a recent study in untrained men has shown that the implementation of periodic DT with subsequent ReT enabled similar hypertrophic responses in bench press strength and muscle mass CSA gains in comparison with participants undergoing continuous training (27).

Participants in this study were identified as resistance trained with a mean training age of 2.8 ± 1.6 years. It is interesting to note that acute elevations in MPS after a heavy resistance exercise session can be mediated by one's training status (11,36). With respect to training status, studies have presented evidence to suggest that resistance-trained individuals elicit an attenuated MPS response after resistance exercise, which mitigates a window of adaptation through which dynamic changes within skeletal muscle can occur (11,22,29,36). Moreover, these anabolic responses are also known to be highly variable between individuals because of a multitude of factors, such as volume load, nutritional intake, age, training status, and genetic predisposition (12,20,29). In addition, research has shown that rapid elevations in strength during the early onset of an RT program may be due to increased neural adaptations before the contribution of hypertrophy (5,32). However, it is important to mention that the variance in strength gains during the onset of RT due to neural adaptations is mainly present within an untrained population. Nevertheless, this study best served to control these aforementioned factors by recruiting resistance-trained individuals, implementing a standardized training program, and also monitoring nutritional intake by dietary records. Additionally, there are no experimental studies to date investigating body composition and muscle performance responses after a DT period, specifically within young, resistance-trained men.

This study explored whether a periodic training program with short-term DT can affect overall fat and lean mass changes. Although the statistical analyses did not reveal a significant effect of group or time on lean mass changes, we observed an average increase in lean mass within the PRO group (1.58 kg) compared with the CHO group (0.34 kg) throughout the entire 10-week training study. Interestingly, 2 weeks of DT in both groups did not produce reductions toward the lean mass gains accrued after 4 weeks of RT (Figure 2). Because we observed no significant changes in TBW or lean mass in either group over the course of the study, this suggests that the short-term cessation of activity still allowed for a retention of lean mass. Although there was no statistical significance, the PRO group continued to increase lean mass during the period of ReT after the 2-week DT period. An explanation behind a lack of statistical significance in lean mass gains throughout the training study may be potentially due to an insufficient daily dietary intake of protein within both groups (Table 3). Studies have shown evidence that an adequate daily protein intake is essential to elicit lean mass gains (3,7). In particular, the International Society of Sports Nutrition's Position Stand on Protein recommended an intake around 1.4–2.0 $g \cdot kg^{-1} \cdot d$ of protein to improve the training adaptations from physical performance in active individuals (3). This study presents evidence that all the participants were consuming approximately 1.1–1.3 $g \cdot kg^{-1} \cdot d$ of protein throughout the training period.

Furthermore, on analyzing the dietary intake recall data, the participants seemed to have been in a hypocaloric state. To further comprehend this finding, a comparison of the participants' total daily energy expenditure (TDDE) to their analyzed dietary intake was implemented for each laboratory session to determine the extent at which the participants' hypocalorism contributed to overall energy balance (Table 3). The TDDE was assessed by calculating the resting energy expenditure (REE) through the utilization of an equation developed by Haaf and Weijs (14), which was based primarily on recreational athletes. Also, this REE value was then multiplied by a physical activity factor commensurate with each participant's respective levels of physical activity to estimate the TDEE needs to maintain their present body mass throughout the training study (14). The TDEE was calculated and compared with the average daily macronutrient consumption and total calories between groups at each respective visit throughout the training study. The comparison of the participant's overall caloric intake and TDDE presented evidence that conditions of overall hypocalorism may have mitigated any impetus for lean mass accretion.

In addition, the lack of overall significant elevations in lean mass within the protein group warrants further discussion. It is widely known that the synergistic interaction between RT and high-quality protein intake can instill a mechanistic overload response with rapid aminoacidemia post-RE to result in a positive net protein balance (13). Although this study did not observe significant elevations in lean mass, this may possibly be due to the time course of the RT period. Training studies with a minimum of 6 weeks of RT and protein supplementation have been shown to induce measureable increases in muscle CSA (8,13,30). However, there has also been contrasting evidence to suggest that accretions in muscle size can occur in a shorter duration of RT (32). Boone et al. (5) observed that there were no significant differences between protein and placebo groups in muscle performance or size changes within the untrained young participants. The protein group received a protein blend comprised 17 g of whey protein concentrate (WPC-80), 3 g of bovine colostrum extract, and 2 g of leucine in contrast to the placebo group with 20 g of resistant maltodextrin. Moreover, the participants ingested the supplement every day during the 28-day training period. It is important to note that this study directed participants to ingest their respective supplement only on training days during the periods of RT and ReT. Nevertheless, in a similar fashion to this study, the researchers observed no additive benefit from protein supplementation on the expected elevations in strength and muscle size during the 28-day period. However, the contrasted body compositional changes from our study may be due to differences in the supplemental intake guidelines, exercise intensity, modality, and, in particular, the participant's training status.

There is also a considerable amount of studies presenting evidence that there is a ceiling effect through which large amounts of protein are not differentially effective in raising MPS compared with a lower dose (21). The research presents evidence to suggest that the ingestion of a 20-g dose of whey protein can maximally stimulate MPS within resistance-trained young men in a similar fashion to a higher dose of 40 g (21). In line with this rationale, this study did not find an additive benefit from including 25 g of whey protein in positive lean mass outcomes within this population. However, it is conceivable that the participants' apparent hypocalorism throughout the training period may take higher credence to the lack of significant gains in positive lean mass irrespective of consistently ingesting 25 g of a whey protein supplement.

In contrast to Ogasawara et al. (27), this study did not observe statistical significance in the RF-CSA changes throughout the entire study. Ogasawara et al. (27) were able to observe significant elevations in muscle CSA after the second 3-week DT/6-week ReT cycle. However, the aforementioned training study investigated only elevations in the CSA of the triceps brachii and pectoralis major muscles and followed a different training regime consisting of 3 cycles of 6-week training with 3-week DT periods to summate a total 24-week period. Additionally, in contrast to this study, Ogasawara et al. (27) recruited untrained (did not participate in regular RT for 2 years) men who performed 1 free-weight bench press exercise 3 days per week as the assigned training load. To this respect, various other studies have presented evidence that a short-term DT period followed by a longer ReT period can allow for improvements in muscle CSA (1,17,24,28).

Interestingly, although not statistically significant, this study did not observe a decrease in the mean RF-CSA changes after 2 weeks of DT. This is in stark contrast to other studies that presented a decreased rate in muscle CSA after a short-term period of DT (24). Andersen et al. (1) observed a significant elevation in the quadriceps CSA after 3 months of RT. Nonetheless, these RT-induced gains were returned to pretraining levels after 3 months of DT (1). Leger et al. (17) also observed that after 8 weeks of RT and atrophy-stimulated DT, half of the training-induced adaptations were retained after the DT period. To reiterate, this study did not observe a decrease in the RF-CSA after 2 weeks of DT (Figure 4). These findings further complicate the optimal degree at which DT can potentially retain muscle mass. Nevertheless, to our knowledge, this study was the first experimental investigation to date that observed a retention of lean mass after a short 2-week period of DT in resistance-trained men, even if it was not statistically significant.

This study has also investigated muscle performance through the assessment of muscular strength and endurance in the LB. Although there was no significant interaction for group or time for LB muscular strength, it is noteworthy to mention that there was no reduction in LPS after 2 weeks of DT (Figure 5). Moreover, the main novel finding was a statistically significant time effect for both DT and ReT in LPS compared with baseline. In simple terms, this means that irrespective of a short-term DT period, LPS continued to increase throughout the entire 10-week training study. Although not statistically significant, this study also specifically observed an increase in absolute LPS irrespective of group after 2 weeks of DT. The CHO group experienced a mean increase from 366.4 ± 60.1 kg (after 4 weeks of RT) to 369.4 ± 61.6 kg (after 2 weeks of DT). Interestingly, the PRO group observed a mean increase from 373.1 kg ± 65.2 kg (after 4 weeks of RT) to 402.25 ± 83.0 kg (after 2 weeks of DT).

There are other studies that have also reported no significant decreases in muscle strength after varied periods of DT (10,15,16,27). Kraemer et al. (16) observed that 6 weeks of DT did not significantly reduce both UB and LB muscle strength. Henwood and Taaffe (15) observed moderate losses in muscle power and strength within older adults (65–84 years) after a 24-week DT period, which was followed after a 24-week RT period. The investigators observed a preservation of training-induced gains within functional performance during DT and also observed comparable accrued improvements after 12 weeks of ReT. Correa et al. (10) also reported partial maintenance of knee extensor strength that was 12% superior to baseline values within elderly women after 12 weeks of training and subsequent 12 weeks of DT. Ogasawara et al. (27) observed similar elevations in 1RM bench press strength between the periodic RT (the first 3-week DT/6-week ReT cycle) and the continuous RT group. Furthermore, during the second periodic RT cycle, there was a significantly higher rate of strength gain compared with that of the corresponding period in the continuous training group. In other words, even with the inclusion of 6 weeks of DT (which comprised 25% less total training sessions) throughout the 24-week training period, the periodic training group presented comparable elevations in 1RM bench press strength compared with the continuous training group.

With respect to muscular endurance, there was no statistical significance in relation to group or time for leg press throughout the study. Despite being supervised by study personnel, one potential explanation behind a lack of convergence in observed findings could be the limitation of a participant not demonstrating a maximum effort during the assessments of endurance. Nevertheless, with respect to muscular performance, the novelty of our study is reporting that muscular strength was retained after a short-term period of DT, which suggests that intermittent periods of DT incorporated within a periodized RT program may still allow strength gains to be maintained within a trained population.

To our knowledge, this study is the first experimental investigation to date exploring the effects of a successive cycle of short-term DT and ReT toward applied variables such as body composition and muscle performance within resistance-trained men. The implementation of a 2-week period of DT seemed to retain lean mass irrespective of a supplemental 25 g intake per day of whey protein. We observed a retention or an increase in LB strength within the CHO and PRO group respectfully after DT. These findings highlight the importance of recovery, as well as the efficacy of periodization to garner elevations in strength and muscle mass. Also, in agreement with Ogasawara et al. (27), these findings present data that suggest that the periodic incorporation of short-term DT may not attenuate the RT-induced anabolic or ergogenic adaptations and may provide an effective means to further progress during a subsequent period of ReT. Because of the interindividual hypertrophic variability based on inherited genetic predisposition, epigenetic influence, age, time-based habitual physical activity, sleep, and training status (19), it is reasonable to deduce that such factors may also explain the widespread variations in hypertrophic events in comparison with the strength data. Nevertheless, it is important to mention that despite the conditions of hypocalorism, the participants in this study were able to increase their muscle strength and also maintain these positive gains after short-term DT.

This study has several limitations that warrant further discussion. Our first major limitation would be the issue of using only 4-day dietary recalls to determine nutritional intakes before each of the testing sessions in this study. It is possible that the information provided from these dietary intakes were not duly reflective of the overall nutritional intake throughout the study. Moreover, a major assumption on solely incorporating a self-reported food consumption log would be the lack of internal control on the participant's self-reports with the expectation that normalized dietary intakes would be upheld throughout the study. Secondly, adherence to the DT protocol is a definite potential limitation. The participants were instructed to comply with the 2-week cessation of training through which only walking was permitted. However, this instruction carries definite assumptions as the only means to ascertain compliance was through consistent communication with verbal agreement with the participants in this study. Thirdly, it is important to note that in contrast to Ogasawara et al. (27), the time course of our training ratio of 4 weeks of RT: 2 weeks of DT: 4 weeks of ReT may not have been long enough to elicit significant elevations in lean mass or RF-CSA changes. Lastly, the analysis of the overall caloric intake presents evidence of a hypocaloric condition in both groups with low dietary protein intake, which may also minimize the true outlook of muscle mass accretion during the course of this training study. Nevertheless, in lieu of these limitations, the efficacy of 2 weeks of DT within a resistance-trained population still necessitates additional research.

In light of our results, we conclude that the integration of a successive cycle of short-term DT before subsequent ReT did not negatively affect LB muscular strength while maintaining lean mass, irrespective of conditions of hypocalorism or additional supplementation of 25 g of whey protein within resistance-trained young men.

PRACTICAL APPLICATION

Previous studies have shown various periods of DT to not affect muscle strength. However, most of these periods of DT were much longer than the 2 weeks involved in this study. For most athletes, and those who consistently resistance train, with the exception of illness or injury, these individuals would most likely not engage in a period of DT longer than 2 weeks without the concern of losing muscle strength and mass. Therefore, the implications of this study toward the general population can be of value with respect to the importance of recovery. Continual periods of chronic mechanical overload could potentially surmount to debilitations in performance because of fatigue, reductions in motivation, or even heightened susceptibility of injury. Therefore, lowering the frequency of exercise sessions through short-term DT could possibly reduce the physical and psychological strain imposed on the recreational weightlifter or athlete. As such, our data do present evidence that 2 weeks of DT can potentially retain previous training-induced muscle mass and strength gains in young, resistance-trained men. To this respect, individuals undergoing an RT program may benefit from using short-term cycles of DT to "recover" and even train for a lesser period of time while still potentially garnering a similar maintenance of strength and muscle mass. Furthermore, these findings can also be potentially translated to athletes through whom short-term periods of DT due to overtraining or temporary muscular injuries may not negatively debilitate previous RT adaptations. However, it is important to note that these findings should be taken with precaution as an optimal time period at which to undergo DT has not been fully elucidated. Our findings observed that a 2:1:2 ratio of training: DT: ReT did not result in a loss of lean mass or LB strength on average within resistance-trained young men.

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