EARLY-PHASE ADAPTATIONS TO A SPLIT-BODY, LINEAR PERIODIZATION RESISTANCE TRAINING PROGRAM IN COLLEGE-AGED AND MIDDLE-AGED MEN

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ABSTRACT

Kerksick, CM, Wilborn, CD, Campbell, BI, Roberts, MD, Rasmussen, CJ, Greenwood, M, and Kreider, RB. Early-phase adaptations to a split-body, linear periodization resistance training program in college-aged and middle-aged men. *J Strength Cond Res* 23(3): 962–971, 2009—An 8-week, split-body, linear periodized resistance training program was completed by college-aged (CA: 18–22 years; $n = 24$) and middle-aged (MA: 35–50 years; $n = 25$) men to determine early-phase adaptations in body composition and upper- and lower-body strength. Participants completed 2 upper-body and 2 lower-body resistance training workouts each week. During weeks 1–4, subjects completed 3–6 sets at a 10-repetition maximum (RM) intensity and increased to 8RM for weeks 5–8. The 1RM strength levels were determined on the bench press and leg press, and 30-second Wingate tests were assessed at baseline and after 8 weeks of resistance training. Body composition was assessed using dual-energy X-ray absorptiometry (DXA). For selected data, delta values (post - pre values) were calculated and reported as mean ± *SEM*. No changes ($p > 0.05$) were reported for peak and average Wingate power. Bench press (CA, 3.2 ± 1.9 kg; MA, 6.2 ± 3.3 kg; $p < 0.001$) and leg press (CA, 25.0 ± 4.4 kg; MA, 18.2 ± 13.3 kg; $p < 0.001$) 1RM significantly increased in both groups over time. Lean mass significantly increased over time in both groups (CA, 0.9 ± 2.4 kg; MA, 1.1 ± 1.9 kg; $p < 0.001$). Significant group × time effects were seen for fat mass changes (CA, 0.5 ± 1.3 kg; MA, −0.5 ± 1.1 kg; $p = 0.01$) and % body fat changes (CA, 0.4 ± 1.4%; MA, −0.7 ± 1.1%; $p = 0.01$). These results indicate that performing a split-body, linearly periodized resistance training program for 8 weeks significantly increases bench press 1RM, leg press 1RM, and DXA lean mass in CA and MA men. Furthermore, MA men lost significantly more fat mass and significantly decreased % body fat compared with CA men. A split-body, linearly periodized resistance training program may be used as an effective program to increase strength and lean mass in both young and MA populations.

KEY WORDS periodization, resistance training, acute training variables

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INTRODUCTION

Resistance exercise continues to be an extremely popular topic among coaches, athletes, personal trainers, and clinical researchers. Furthermore, research is continuously elucidating how different resistance exercise prescriptions affect outcome variables such as changes in body composition and/or performance variables. It is well established that some degree of periodization is necessary to optimize training adaptations. The most popular and established forms of periodization are linear and undulating. In short, linear periodization (LP) gradually increases the training intensity while decreasing the training volume between microcycles, whereas undulating periodization (UP) is characterized by more frequent changes (i.e., changes within a training week or training session) in intensity and volume. Willoughby (30) compared an LP vs. a non-periodized 16-week program in trained subjects and found that men after the LP model experienced greater increases in upper- and lower-body strength. Similarly, Kraemer et al. (17)

investigated the body composition, strength, endocrine, and performance adaptations of a fixed-load vs. UP program in collegiate female tennis players after a 9-month training period. Subjects in the UP group completed 2–3 sets of 4- to 6-repetition maximum (RM) loads on Mondays, 8–10RM loads on Wednesdays, and 12–15RM loads on Fridays for 11 full-body exercises, whereas the fixed-load group performed 8–10RM loads for the respective workout days throughout the 9-month program. The authors found that although both training regimens yielded similarly favorable changes in endocrine and body composition markers, athletes participating in UP had greater increases in upper- and lower-body strength as well as sport-specific performance variables after 6 and 9 months of training.

To date, multiple studies have evaluated performance, hormonal, physiological, and biochemical changes as a result of resistance exercise. A 2004 review by Fry (12) used a linear regression model of 16 studies to find that exercise intensity was the most important variable for stimulating muscle growth. Fry concluded that the optimal training intensity range for muscular hypertrophy is between 80 and 95% of 1RM, which corresponds to 6–10RM. In 2002, Kraemer et al. (14) cited more than 250 research articles in developing the American College of Sports Medicine (ACSM) position stand on resistance training prescription. The authors conclude that to stimulate maximal muscular hypertrophy, 3–4 workouts per week using moderate loads of 70–85% 1RM should be used, with 8–12 repetitions per set and 1–3 sets per exercise. A weekly split-body program provides a convenient training model because it allows individuals to train at the recommended frequency as well as the ideal intensity (i.e., 70–85% 1RM) and volume (i.e., 3 sets of 6–10RM loads) while also providing adequate recovery of all involved body parts for 72 hours. Split-body programs also may enable trainees to train at a higher daily training intensity level compared with full-body programs because isolating upper- vs. lower-body muscles on different training days is presumably less energetically taxing than a full-body workout. For example, past research in our laboratory employing a split-body routine enables trainees to perform 21–24 sets of upper- or lower-body exercises per day compared with 30 sets of full-body exercises per day. Thus, although both of these programs are isovolumic, trainees perform fewer sets per training session while having more recovery per muscle group between training sessions. It should be noted that the aforementioned split-body routines have yielded favorable alterations in body composition and muscular performance without any deleterious side effects (i.e., excessive soreness and/or musculoskeletal injury) (13). Regardless, such studies have primarily used young, college-aged (CA) men, and no study has investigated how middle-aged (MA), recreationally weight-trained men respond to this model of periodization in comparison with CA men. Research has commonly reported that aging results in decreases of strength and muscle mass chiefly because of a loss in functional motor units (18), decreases in anabolic hormones and growth factors (i.e., testosterone, human growth hormone, insulin-like growth factor I [IGF-I], muscle-derived IGF-IEa, etc.) (23), mitochondrial DNA damage causing malfunctioned mitochondrial biogenesis (which leads to energy deficits and subsequent muscle atrophy), and a diminished ability to synthesize myofibrillar proteins (25). Regardless, regular resistance exercise using an adequate training volume and intensity has been suggested to mitigate the aforementioned phenotypic changes (15). In addition, some studies have suggested that older populations can experience increases in strength and body composition in much the same fashion as a young cohort, although other studies have reported no differences in the training adaptations made by these groups (21). However, no study to our knowledge has examined whether periodization further enhances body composition and/or performance parameters in previously trained MA men. Furthermore, the limited data examining the training adaptations accrued after an LP resistance exercise program in previously trained populations obviate further investigation. Therefore, the purpose of this study is to compare the changes in strength and body composition variables in a younger (18–22 years) and older (35–50 years) group of previously resistance-trained men after an LP, split-body resistance training program of 8 weeks duration.

Methods

Experimental Approach to the Problem

The primary objective was to compare how CA vs. MA individuals would respond to a split-body LP resistance training program. We chose our exercise intervention to include the split-body LP workout because it is a relatively novel regimen with little research supporting or dismissing its efficacy. The time frame chosen for this study was based on previous research deeming that subjects participating in a novel, short-term (i.e., 8–10 weeks) resistance exercise regimen is adequate for inducing positive training adaptations (2,13,15). The 1RM bench press and 1RM leg press were used in the present study as criterion measures of strength, and Wingate cycling tests were completed for measures of anaerobic capacity (e.g., peak and average power). Finally, dual-energy X-ray absorptiometry (DXA) scans were used to track changes in body composition following similar research using the DXA to track body composition changes in participants after a resistance training protocol. All subjects in this study were matched into clusters according to age and fat-free mass before beginning the 8-week resistance training program. We defined MA as being 35–50 years old, and our mean age in the MA group is numerically similar to other literature that has examined the effects of resistance training in a similar population (9). We defined CA individuals as predominantly between the ages of 18–22, following previous research (12,13). All subjects were tested at 0 and 8 weeks to determine the changes in criterion variables. It was hypothesized that the split-body LP resistance training program would increase strength and power and promote favorable changes in body composition in both the CA and MA groups, with no differences between the 2 age groups.

Subjects

Forty-nine apparently healthy men between the ages of 18 and 50 years volunteered to participate in this study. Subjects were informed as to the experimental procedures and signed informed consent statements and medical history forms in adherence with the human subjects guidelines of Baylor University and ACSM before any data collection. Baseline demographics are presented in Table 1.

Procedures

Entrance Criteria. To participate in this study, subjects had to 1) sign statements indicating they had no current or past use of anabolic steroids; 2) be experienced with resistance training (> 1 year) and currently training > 3 h·wk^{-1}, including both the bench press and leg press/squat exercises; 3) not regularly participate in endurance training > 20 minutes per session (e.g., running, cycling, swimming) for the entire study; 4) have not ingested or currently be ingesting creatine, β-hydroxy-β-methylbutyrate, thermogenics, or other nutritional supplements (excluding multivitamins) for an 8-week period before beginning the study; 5) agree to follow the split-body LP resistance exercise program; 6) be classified as low risk according to ACSM (7) criteria with no medical contraindications to resistance exercise; and 7) abstain from a dietary program that might confound the results of the study (vegetarian diet, caloric and/or macronutrient restriction, food allergies, etc.).

Familiarization and Testing Sessions. Each subject participated in 1 familiarization session and 2 identical testing sessions. Informed consent statements and medical and exercise history forms were completed. During the familiarization session, each subject performed practice trials of strength and anaerobic capacity equipment before receiving instructions concerning proper exercise technique, proper recording of training data (lifts performed, repetitions, amount of weight lifted, etc.), and recording nutritional intake. Specifically, participants recorded all food and liquid consumed during a 4-day period, which consisted of 3 weekdays and 1 weekend day before and after completing the study. Detailed instructions were also provided with regard to estimating portion sizes and logging food preparation (e.g., logging grilled vs. fried foods).

Participants reported to the lab for the baseline testing session (W0) between the hours of 08:00 and 10:00, 1 week after the familiarization session, to allow time for adequate recovery and baseline nutritional logging. The W0 testing included 1) a 4-day dietary record, 2) measurement of body mass and body composition assessment using DXA as previously described (1), 3) 1RM strength tests on the bench press and leg press, and 4) anaerobic capacity using a Wingate anaerobic capacity test on a computerized cycle ergometer (Lode Excalibur, Lode, Groningen, The Netherlands). After W0, subjects were assigned to either the CA (18–22 years old) or the MA group (35–50 years old) and began the training protocol the Monday after W0. Participants returned to the lab after the 8-week protocol for posttraining assessments (W8). In an effort to control for diurnal variations in endocrine hormones (testosterone, human growth hormone, etc.), subjects returned to the lab for W8 the same as their baseline testing. Subjects also returned the second 4-day dietary log before follow-up testing to ensure that their dietary habits had not changed throughout the study. Subjects underwent testing procedures that were identical to those of the W0 testing session. In short, subjects had their body composition determined using identical testing procedures, completed 1RM testing on both the leg press and bench press, and completed a 30-second Wingate anaerobic capacity test.

Body Composition Analysis. Subjects fasted for 8 hours and refrained from resistance exercise for 48 hours before W0 and W8. During W0 and W8, body weight was obtained using a calibrated Healthometer digital strain gauge electronic scale (Bridgeview, Ill) with a precision of ±0.02 kg. Each subject then had his whole-body (excluding cranium) composition estimated following previous procedures (12,13) using a Hologic QDR-4500W DXA and Hologic software version 9.80C (Waltham, Mass). The DXA scans regions of the body (i.e., right arm, left arm, trunk, right leg, left leg) to determine bone mass, fat mass, and lean mass within each region. The scanned bone, fat, and lean mass for each region were then subtotaled to determine whole-body (excluding

Table 1. Subject demographics (mean ± *SD*).

Variable	College aged ($n = 24$)	Middle aged ($n = 25$)
Age (y)	19.8 ± 1.5	41.9 ± 4.3*
Height (cm)	179.2 ± 6.7	177.5 ± 5.9*
Weight (kg)	81.3 ± 8.3	88.8 ± 10.4*
DXA percent fat (%)	14.3 ± 5.1	20.1 ± 5.5
Weekly training (h·wk^{-1})	6.6 ± 3.9	6.0 ± 3.5
Days training (d·wk^{-1})	4.5 ± 1.1	4.4 ± 0.9

DXA = dual-energy X-ray absorptiometry.
*Middle aged > college aged ($p < 0.05$).

cranium) values. Body fat percentage was determined with the Hologic software by dividing the amount of fat mass by the total scanned mass (bone mass, fat mass, and lean mass). Standard calibration procedures were completed on a daily basis before each testing session according to procedures previously described (12,13). The DXA has been found to be a highly reliable method of determining soft-tissue body composition and percent body fat for the whole body and all respective regions determined (11,19).

Strength Testing. After body composition analysis, subjects completed a 1RM for both the bench press and leg press. For bench press, 2 warm-up sets of 10 repetitions at about 50% 1RM were completed before following 3–5 progressive 1RM attempts with 2 minutes of rest in between attempts using a standard 20-kg barbell and a standard bench found in many fitness facilities. Grip width was recorded and standardized between trials. Subjects were required to maintain good lifting form (i.e., feet in contact with the floor, buttocks remaining in contact with bench, no bouncing of the bar off of the chest) during all lifts. Once bench press 1RM was determined, subjects were given 5 minutes of rest before following similar procedures to determine the 1RM with the leg press. Leg press 1RM was completed using a stand 35° hip sled/leg press (Nebula Fitness, Ohio). Each subject was positioned flat on his back in an adjustable back/shoulder support, which was adjusted to allow the subject to be positioned with the thighs approximately 1–2 inches from the torso and the knees at an angle approximately equal to 90° with the feet comfortably positioned. Sled position and foot placement were standardized between testing sessions, and all subjects were required to maintain good lifting form (i.e., hands/forearms at their sides with the lower back flat on the back pad). Subjects typically used 4–6 attempts to achieve their leg press 1RM while appropriately adjusting the weight, with 2 minutes of rest between attempts, until their 1RM was determined. During both testing sessions, subjects were advised to employ the aforementioned lifting criteria and were verbally encouraged by the testers.

Average and Peak Power Testing. Subjects completed a 30-second Wingate anaerobic capacity sprint test on a cycle ergometer. As mentioned previously, the sprint tests were performed on a computerized cycle ergometer equipped with toe clips at a standardized torque factor of 0.075 $kg \cdot kg^{-1}$ body weight. The torque factor was chosen according to the population used in the study and manufacturer recommendations. Subjects were instructed to stay seated throughout the entire protocol and to begin sprinting 5 seconds before the onset of the testing period. The Excalibur Sport has an accurate testing range of 0–2000 W, with a typical variation of measurement $< 2\%$ and a sampling frequency of 5 times per second.

Linearly Periodized, Split-Body Training Protocol. Each participant was instructed to report to the study coordinator each week to log any adverse events as well as compliance to the training protocol. The training program consisted of 4 workouts per week (i.e., 2 upper body and 2 lower body) in an LP, split-body fashion, which primarily used multijoint exercises that targeted all major muscle groups. Table 2 provides a layout of the exact training program.

Subjects were instructed to rest 1 minute between sets and 2 minutes between each exercise. Furthermore, subjects were told to exercise at a load that induced muscular fatigue during the last repetition of each set to ensure that an adequate training stimulus was attained (28). All workouts were completed at each participant's own training facility, and training compliance and supervision was verified by having a training partner or fitness instructor/personal trainer sign off on each workout completed. Subjects were instructed to maintain their normal diet throughout the supplementation and training period. All subjects began following the resistance program the Monday after their baseline testing for 8 consecutive weeks, for a total of 32 workouts. All dietary

Table 2. Resistance training program.

Weeks	Monday, Thursday*†	Tuesday, Friday*†
1–4	Bench press, 3 × 10	Leg press, 3 × 10
	Chest flies, 3 × 10	Leg extensions, 3 × 10
	Lat pull, 3 × 10	Deadlift, 3 × 10
	Seated row, 3 × 10	Lunges, 3 × 10
	Shoulder press, 3 × 10	Lying leg curls, 3 × 10
	Shoulder shrugs, 3 × 10	Heel raises, 3 × 10
	Bicep curls, 3 × 10	Ab crunches, 3 × 25
	Triceps extension, 3 × 10	
5–8	Bench press, 3 × 8	Leg press, 3 × 8
	Chest flies, 3 × 8	Leg extensions, 3 × 8
	Lat pull, 3 × 8	Deadlift, 3 × 8
	Seated row, 3 × 8	Lunges, 3 × 8
	Shoulder press, 3 × 8	Lying leg curls, 3 × 8
	Shoulder shrugs, 3 × 8	Heel raises, 3 × 8
	Bicep curls, 3 × 8	Ab crunches, 3 × 25
	Triceps extension, 3 × 8	

*One minute of rest between sets.
†Two minutes of rest between exercises.

records were analyzed using the ESHA Food Processor (Version 8.6) software (ESHA Research; Salem, Ore) and were reviewed by the laboratory dietician. Unavailable foods were entered into a database from the manufacturer label. A 4-day average of caloric intake, carbohydrate intake, protein intake, and fat intake relative to body mass was computed for later statistical analysis to ensure that caloric and macronutrient intake did not change throughout the study.

TABLE 3. Average dietary intake normalized to body weight in kilograms for the college-aged (CA) and middle-aged (MA) subjects given as mean ± *SD*.

Variable	Group*	Mean ± *SD*	Significance
Energy intake ($kcal \cdot kg^{-1} \cdot d^{-1}$)	CA	35.8 ± 6.8	0.061
	MA	32.0 ± 7.1	
Carbohydrate intake ($g \cdot kg^{-1} \cdot d^{-1}$)	CA	4.5 ± 1.3†	0.005†
	MA	3.6 ± 0.8	
Protein intake ($g \cdot kg^{-1} \cdot d^{-1}$)	CA	1.8 ± 0.9	0.315
	MA	1.5 ± 0.5	
Fat intake ($g \cdot kg^{-1} \cdot d^{-1}$)	CA	1.2 ± 0.4	0.720
	MA	1.2 ± 0.3	

*CA group: $n = 24$; MA group: $n = 25$.
†CA > MA ($p < 0.05$).

Reliability

Previous test-retest reliability analyses of 10 similar individuals from our lab have yielded the following intraclass correlation coefficients (ICCs) and minimum difference values for these tested dependent variables: Wingate average power (ICC = 0.94), Wingate peak power (ICC = 0.83), 1RM bench press (ICC = 0.98), and 1RM leg press (ICC = 0.97). There were no significant differences ($p > 0.05$) between any of the above-mentioned test-retest values.

Statistical Analyses

Separate 2 × 2 (age × testing session) analyses of variance (ANOVA) with repeated measures were used to determine main and group interactions for all criterion variables using the SPSS for Windows version 11.5 statistical package (Chicago, Ill). Data were considered significantly different when the probability of error was 0.05 or less. Delta scores (post - pre values) were calculated on selected variables and analyzed using 1-way ANOVA. Data in tables are presented as mean ± *SD*, and data in all figures for improvement in clarity

TABLE 4. Body composition changes for the college-aged (CA) and middle-aged (MA) subjects given as mean ± *SD*.

Variable	Group*	Week 0	Week 8	Significance	
Body mass (kg)	CA	81.3 ± 8.3	82.0 ± 8.6	Group	0.009§
	MA	88.8 ± 10.4	89.3 ± 10.4	Time	0.059
				Group × time	0.830
DXA total scanned mass (kg)	CA	74.7 ± 8.0	76.1 ± 8.1	Group	0.010§
	MA	81.9 ± 9.8	82.6 ± 9.9	Time	0.003†
				Group × time	0.333
DXA lean mass (kg)	CA	61.2 ± 6.1	62.1 ± 6.1	Group	0.364
	MA	62.7 ± 6.4	63.8 ± 6.5	Time	0.001†
				Group × time	0.574
DXA fat mass (kg)	CA	10.8 ± 4.6	11.3 ± 4.7	Group	0.001§
	MA	16.8 ± 6.0	16.3 ± 6.0	Time	0.779
				Group × time	0.011‡
DXA fat-free mass (kg)	CA	63.7 ± 6.4	64.6 ± 6.4	Group	0.408
	MA	65.1 ± 6.7	66.2 ± 6.7	Time	0.001†
				Group × time	0.770
DXA body fat (%)	CA	14.3 ± 5.1	14.7 ± 5.1	Group	0.001§
	MA	20.1 ± 5.5	19.4 ± 5.5	Time	0.374
				Group × time	0.006‡

DXA = dual-energy X-ray absorptiometry.
*CA group: $n = 24$; MA group: $n = 25$.
†Significant main effect for time ($p < 0.05$).
‡Greater increase over time for CA compared with MA ($p < 0.05$).
§Significant main effect for group where MA > CA ($p < 0.05$).

TABLE 5. Maximal strength (1-repetition maximum [1RM]) changes and percent change in Wingate anaerobic capacity for the college-aged (CA) and middle-aged (MA) subjects given as mean ± *SD*.

Variable	Group*	Week 0	Week 8	Significance	
Bench press 1RM (kg)	CA	100.3 ± 17.9	103.5 ± 16.0	Group	0.902
	MA	99.5 ± 24.3	105.7 ± 21.0	Time	0.000†
				Group × time	0.141
Leg press 1RM (kg)	CA	288.3 ± 80.0	313.26 ± 84.4	Group	0.015‡
	MA	225.5 ± 62.5	243.7 ± 75.8	Time	0.000†
				Group × time	0.417
% Change in peak power (W)	CA	–	4.85 ± 15.6		
	MA		−0.29 ± 14.2		
% Change in average power (W)	CA	–	1.00 ± 10.5	*p*	0.414
	MA		4.00 ± 14.5		

*CA group: $n = 24$; MA group: $n = 25$.
†Significant main effect for time ($p < 0.05$).
‡Significant main effect for group effect where CA > MA ($p < 0.05$).

are presented as mean ± *SEM*. Cohen *d* effect size calculations were calculated whereby $d = 0.2$, 0.5, and 0.8 were considered small, medium, and large treatment effects, respectively. A priori analysis using power analysis software (G*power, v. 3.0.8) determined that we needed 21 subjects per group to detect a large ($d = 0.8$) effect at a power of 0.8 (6).

RESULTS

Nutritional Data

All nutritional data are represented relative to body weight in kilograms (Table 3). No significant differences were reported for total relative caloric intake ($p = 0.06$), protein ($p = 0.32$), or fat intake ($p = 0.72$). The CA subjects consumed significantly more carbohydrates than did the MA subjects throughout the duration of the study ($p = 0.005$).

Training Volume and Previous Training Status

Relative training volume throughout the duration of the study (i.e., sets × reps × weight lifted) was normalized to body weight in kilograms (kilograms lifted / kilograms of body mass) for all subjects. Statistical analysis revealed that no significant differences existed ($p > 0.05$) between either of the age groups for both upper-body (CA: 3872 ± 917 kg·kg^{-1}; MA 4310 ± 1163 kg·kg^{-1}; $p = 0.15$) and lower-body (CA: 4531 ± 1050 kg·kg^{-1}; MA: 4748 ± 1274 kg·kg^{-1}; $p = 0.52$) total training volume. No significant difference was found between age groups in the number of hours they trained per week (CA: 6.6 ± 3.8 h·wk^{-1}; MA: 6.1 ± 3.4 h·wk^{-1}; $p = 0.61$) or days trained per week (CA: 4.5 ± 1.1 d·wk^{-1}; MA: 4.4 ± 0.89 d·wk^{-1}; $p = 0.77$) before the 8-week training regimen.

Medical Monitoring. No significant clinical side effects, related or unrelated to the study, were reported throughout the

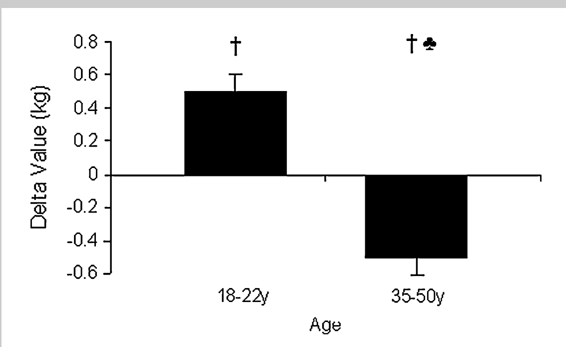

Figure 1. Delta (week 8 − week 0) value for dual-energy X-ray absorptiometry fat mass (kg) after 8 weeks for college-aged (CA; $n = 24$) and middle-aged (MA; $n = 25$) subjects. Data are presented as delta (week 8 − week 0) mean ± *SD*. †Significant increase from T0 ($p < 0.05$); ♣greater increase over time for MA compared with CA ($p < 0.05$).

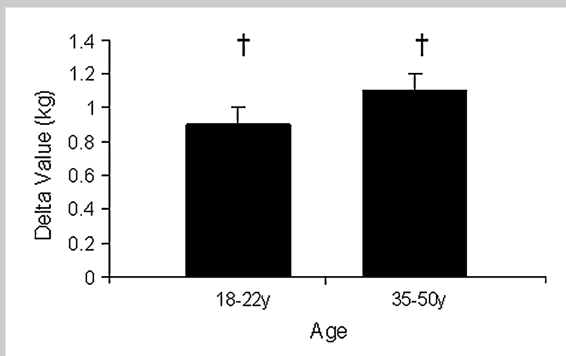

Figure 2. Delta (week 8 − week 0) value for dual-energy X-ray absorptiometry lean mass (kg) after 8 weeks for college-aged (CA; $n = 24$) and middle-aged (MA; $n = 25$). Data are presented as delta (week 8 − week 0) mean ± *SD*. †Significant increase from T0 ($p < 0.05$).

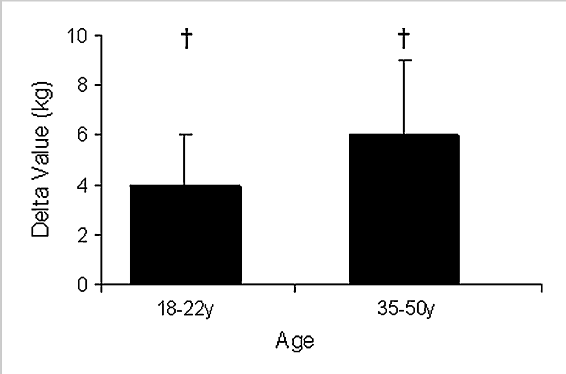

Figure 3. Delta (week 8 − week 0) value for bench press 1-repetition maximum (1RM, kg) after 8 weeks for college-aged (CA; $n = 24$) and middle-aged (MA; $n = 25$). Data are presented as delta (week 8 − week 0) mean ± *SD*. †Significant increase from T0 ($p < 0.05$).

course of the study. All subjects tolerated all testing and resistance training protocols without any problems.

Body Composition. Table 4 presents body mass and body composition for both groups. Body mass tended to increase in both groups after the 8-week regimen, but these gains were not statistically significant ($p = 0.06$). Increases in DXA total scanned mass, DXA fat-free mass, and DXA lean mass occurred similarly in both groups after the 8-week protocol ($p < 0.01$). A significant group effect illustrated greater values of body mass, DXA total scanned mass, DXA fat mass, and DXA percent body fat across the entire study in comparison with the CA group ($p < 0.05$). Delta changes in DXA fat mass (CA: 0.5 ± 1.3 kg; MA: -0.4 ± 1.1 kg; $p = 0.01$; $d = 0.66$) and percent body fat (CA: 0.5 ± 1.5%; MA: -0.7 ± 1.1%; $p < 0.01$; $d = 0.51$) revealed significant group × time interactions and moderate effect sizes, respectively. Post hoc analysis revealed a significant ($p < 0.05$) increase in the fat mass of CA subjects compared with MA, which also accounted for the significant increases in DXA body fat percentage in the young group (Figures 1 and 2).

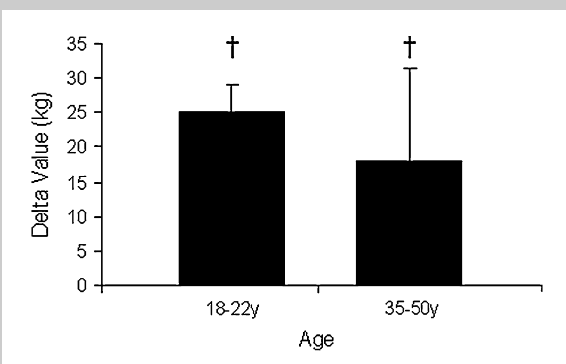

Figure 4. Delta (week 8 − week 0) value for leg press 1-repetition maximum (1RM, kg) after 8 weeks for college-aged (CA; $n = 24$) and middle-aged (MA; $n = 25$). Data are presented as delta (week 8 − week 0) mean ± *SD*. †Significant increase from T0 ($p < 0.05$).

Performance Measures

Table 5 presents performance measures for both groups. Bench press 1RM and leg press 1RM significantly increased over time for both age groups ($p < 0.001$). No changes ($p > 0.05$) were noted for percent change in Wingate peak power and average power. It should be noted that there were no significant group effect differences in 1RM bench press strength ($p = 0.90$) throughout the duration of the study, although there were significant group effect differences in bench press strength, with CA being significantly higher throughout the study ($p = 0.02$) (Figures 3 and 4).

Discussion

This study examined changes in maximal strength, anaerobic capacity, and body composition after an 8-week, split-body, LP resistance training program in both a CA and MA cohort. Although different periodization models exist, available research on following a split-body program is limited. Furthermore, research concerning the physiological effects of periodized resistance exercise has been limited to trained CA women (16,17), untrained (15,24,26) and recreationally trained CA men and women (2,20), and untrained elderly men (15). Incorporation of this periodization model would further enhance resistance training adaptations in younger and MA individuals. It was hypothesized that both groups would respond in a positive but similar fashion regarding changes in strength and body composition. Our findings suggest that maximal strength increased in both groups after 8 weeks of LP, which supports our original hypothesis. Changes in anaerobic capacity, however, were not noted in this study.

Although no general consensus is accepted regarding which style of periodization is most appropriate, several different schemes exist. A linear model is the most common model, although reverse LP and UP programs are increasing in popularity (24). The endocrine and intramuscular changes that occur with LP across 8 weeks have been previously researched by Staron and colleagues (26). The authors discovered that dynamic strength increased for squats, leg presses, and leg extensions after 4 weeks of training. Type IIb fiber number decreased after 4 weeks in men, whereas the percentage of type IIa fibers trended upward. Furthermore, resting testosterone levels increased and remained significantly elevated after 4 weeks, whereas resting cortisol levels decreased and remained depressed after 6 weeks of training in men. The authors conclude that when skeletal muscle is unaccustomedly stressed with a hypertrophic stimulus (i.e., resistance exercise with moderate intensity and higher lifting volumes) over very short periods (i.e., 2–4 weeks), phenotypic changes that lead to strength gains are incurred. The significant increases in both bench press and leg press 1RM found in the present study were also in accordance with findings from previous studies on different models of periodization (16,17,24,30). Two of these studies (16,17) used female collegiate athletes to determine the changes in strength after either 6 or 9 months of periodized resistance training. In both studies, significant increases in upper- and lower-body strength were found. Additionally, Rhea et al. (24) investigated changes in maximal strength after an LP program or a daily UP program. In accordance with the current study, significant increases in bench press and leg press 1RM were found in previously trained CA men. Lastly, a study by Newton et al. (21) observed younger and older men for 10 weeks as they completed a periodized resistance training program for changes in strength, maximal power, rate of force development, and muscle activation. In this study, significant increases in isometric strength and rate of force development were found in both groups over time, whereas maximal power output was greater in the younger group at all time points. As with the current study, the lack of change associated with anaerobic capacity after a periodized resistance training program has been previously reported (3,13). This phenomenon can likely be attributed to the specificity of training, because the greatest loads used in this program (i.e., 8RM) were not ideal in inducing gains in power production (28). Collectively, findings from the current study and those from previously reported studies lend support to using split-body LP resistance exercise programs to promote positive adaptations in CA and MA populations.

Significant improvements in body composition were hypothesized to occur in both groups after the 8-week, split-body, LP resistance training program. Interestingly, both groups experienced significant increases in lean mass and fat-free mass, with no difference between the groups. Vast research suggests that the growth potential of older individuals is limited by several intracellular and endocrine factors. Furthermore, exercise scientists have shown that myofibrillar accretion occurring hours after exercise is contingent on translational mechanisms, whereas longer-term hypertrophy is likely attributable to increases in the number of myonuclei per muscle fiber (i.e., myonuclear domain theory) via satellite cell activation, differentiation, and fusion to preexisting muscle fibers (23). Thus, perhaps the most prevalent phenomenon contributing to an age-dependent decrease in muscle hypertrophy potential in older exercising individuals includes a reduction in satellite cell number per type II muscle fiber (27) and a decreased ability to activate/recruit satellite cells because of decreases in endocrine and autocrine/paracrine muscle-specific growth factors with aging (chiefly testosterone and IGF-IE variants, respectively) (23). Regarding translational mechanisms, Parkington and colleagues (22) used Brown Norway rats to illustrate that there is an attenuated response in mammalian target of rapamycin and $p70^{S6K}$ phosphorylation with skeletal muscle aging after a high-intensity muscle activation protocol. The authors conclude that these mechanisms likely reduce muscle protein synthesis and the accumulation of myofibrillar protein with aging. More recent evidence confirming the conclusions of Parkington et al. found that humans aged 62–74 years presented decreased rates in muscle protein synthesis (reportedly 33% and 27% slower than CA adults before and after 3 months of resistance training, respectively) compared with younger counterparts as determined by the incorporation of L-ring ^{13}C leucine into myofibrillar proteins (29). Nonetheless, although these studies offer invaluable insight as to how muscle aging diminishes hypertrophic capabilities, all of the above-mentioned literature examined animals and humans older than our MA cohort. Furthermore, our findings are in agreement with past literature citing that older age groups can accrue similar increases in strength and lean mass, as long as the exercise stimulus is of an appropriate training volume and intensity (4,21).

The MA group also presented an unexpected but significant reduction in fat mass and changes in % body fat in comparison with the CA group during the 8-week period. Changes in body composition in older populations are thought to be somewhat blunted in comparison with younger cohorts because of decrements in resting metabolic rate, lean tissue mass, and intramuscular energy metabolism (i.e., decreases in mitochondrial density and other glycolytic/lipolytic enzymes) (8). Although the periodization scheme under investigation was not traditional, the volume and intensity prescription were similar to those from previous research reporting increases in muscle mass only in younger and older men (15). Thus, it is unlikely that any novel aspect of the training program was responsible for theses changes in body composition with the MA group. Although no changes were found in relative caloric, protein, and fat intake between age groups, the CA group did consume significantly more carbohydrate (CA: 4.5 ± 1.3 $g \cdot kg^{-1} \cdot d^{-1}$; MA: 3.6 ± 0.8 $g \cdot kg^{-1} \cdot d^{-1}$). This difference amounted to approximately 50 more grams of carbohydrate being consumed per day, which, during the course of the 8-week investigation, might have accounted for the additional 0.5 kg of fat mass that was reported in the CA cohort. In contrast, the CA group reported at baseline a higher level of physical activity. Consequently, the greater level of daily physical activity in the CA group may have negated energy consumption differences between groups. Furthermore, no conclusive evidence links additional carbohydrate intake to the increases in % body fat that were found in the CA group (1,5). Although various studies have suggested that high and low glycemic index foods differentially impact circulating levels of glucose and insulin as well as subsequent lipogenesis (1), it is not possible to conclude that CA gained fat mass from extraneous carbohydrate intake, because of the lack of available nutritional information from the dietary records. Moreover, circulating levels of glucose and/or insulin were not assessed at any point in this study, which further obscures this suggestion. The possibility also remains that although the MA group had previously trained approximately 6 h·wk^{-1} and exhibited strength values similar to those of trained MA populations in the literature (further validating their training status) (10), the decreases in fat mass could have occurred in response to an increase in training volume during the 8-week period relative to their prestudy training volumes without increasing calorie intake. Again, however, these assumptions currently cannot be validated.

In summary, a short-term, split-body, LP resistance exercise protocol seems efficacious in improving muscle mass after 8 weeks in previously trained CA and MA men. Additionally, the MA group may respond more favorably regarding changes in body composition (i.e., decreasing body fat percentage), although this hypothesis should be investigated further.

Practical Applications

Periodization of resistance training is one of the most popular means of exercise prescription for resistance training. A split-body LP resistance training program is an approach that has not commonly been used by strength coaches and resistance training athletes. Although the training adaptations that are likely to occur may be similar to full-body periodization regimens, the advantages of this program allow for all similar muscle groups to be trained during the same workout while allowing for a greater recovery (i.e., 72 vs. 48 hours) before the subsequent workout. This approach could be used by personal trainers, strength coaches, and resistance training athletes as an effective alternative to training the entire body for a 1-week period in younger and older trained individuals.

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