Influence of Resistance Training Frequency on Muscular Adaptations in Well-Trained Men

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Abstract

Schoenfeld, BJ, Ratamess, NA, Peterson, MD, Contreras, B, and Tiryaki-Sonmez, G. Influence of resistance training frequency on muscular adaptations in well-trained men. *J Strength Cond Res* 29(7): 1821–1829, 2015—The purpose of this study was to investigate the effects of training muscle groups 1 day per week using a split-body routine (SPLIT) vs. 3 days per week using a total-body routine (TOTAL) on muscular adaptations in well-trained men. Subjects were 20 male volunteers (height = 1.76 ± 0.05 m; body mass = 78.0 ± 10.7 kg; age = 23.5 ± 2.9 years) recruited from a university population. Participants were pair matched according to baseline strength and then randomly assigned to 1 of the 2 experimental groups: a SPLIT, where multiple exercises were performed for a specific muscle group in a session with 2–3 muscle groups trained per session ($n = 10$) or a TOTAL, where 1 exercise was performed per muscle group in a session with all muscle groups trained in each session ($n = 10$). Subjects were tested pre- and poststudy for 1 repetition maximum strength in the bench press and squat, and muscle thickness (MT) of forearm flexors, forearm extensors, and vastus lateralis. Results showed significantly greater increases in forearm flexor MT for TOTAL compared with SPLIT. No significant differences were noted in maximal strength measures. The findings suggest a potentially superior hypertrophic benefit to higher weekly resistance training frequencies.

Key Words muscle strength, muscle hypertrophy, split routine, full-body routine

Introduction

Proper manipulation of resistance training (RT) variables is considered essential to optimize postexercise muscular adaptations (13). One variable that can be manipulated to bring about desired results is the frequency of training. By most definitions, frequency of training pertains to the number of exercise sessions performed in a given period and is generally expressed on a weekly basis. However, another important aspect of frequency is the number of times a specific muscle group is trained over the course of a given week. Despite speculation on the topic, the optimal training frequency for a muscle group has yet to be determined (30).

As a general rule, those involved in RT programs with hypertrophy as a primary goal train each muscle group relatively infrequently but perform a high volume of work per muscle group in a session. This is accomplished using a split-body routine (SPLIT), where multiple exercises are performed for a specific muscle group in a training bout. Compared with full-body routines, it is believed that a split routine allows total weekly training volume per muscle group to be maintained with fewer sets performed per training session and greater recovery afforded between sessions (11). In addition, working a muscle with a greater training volume in the same session helps to increase intramuscular metabolic stress (8), which in turn may enhance the hypertrophic response to the exercise bout (24). A recent survey of 127 competitive male bodybuilders found that more than two-thirds of respondents trained each muscle group only once per week (9). Moreover, none of the respondents trained a muscle group more than twice weekly and every respondent reported using a SPLIT (9). This is in contrast to weightlifters and powerlifters, who tend to train muscles more frequently using total-body routines (TOTAL) (7).

Previous work from our laboratory showed no differences in muscle hypertrophy when well-trained lifters performed a volume-equated split- vs. total-body training regimen (25). However, this study used different loading and rest interval schemes, thereby confounding the ability to draw conclusions specific to training frequency. To the authors' knowledge, only 1 published study has directly compared muscular adaptations when training muscles with a weekly frequency of 1 vs. 3 days. McLester et al. (17) evaluated the volume-equated effects of 1 day vs. 3 days of RT per week on maximal strength and body composition. After 12 weeks, increases in 1 repetition maximum (RM) and lean body mass

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were greater in the 3-day-a-week group, indicating that a greater frequency of training promotes superior muscular adaptations. The study was limited by the use of indirect hypertrophic measures (i.e., skinfold technique) to measure changes in body composition; direct measurement of muscle growth was not endeavored. Moreover, the total weekly volume was low compared with typical bodybuilding routines, with subjects performing only 3 weekly sets per muscle group. These limitations make it difficult to draw conclusions as to differences in muscular adaptations between protocols. Therefore, the purpose of this study was to investigate the effects of training muscle groups 1 day per week using a SPLIT vs. 3 days per week using a TOTAL (where the number of sets per muscle group was equated) on muscular adaptations in well-trained men. This study used high volumes typically associated with bodybuilding-style training and the use of validated diagnostic imaging methods to assess changes in muscle thickness (MT). It was hypothesized that the SPLIT would promote greater muscular hypertrophy compared with the TOTAL because of greater metabolic stress, but the TOTAL would promote greater strength gains compared with the SPLIT as a result of more frequent neural stimulation.

Methods

Experimental Approach to the Problem

Participants were pair matched according to baseline strength and then randomly assigned to 1 of the 2 experimental groups: a SPLIT, where multiple exercises were performed for a specific muscle group in a session with 2–3 muscle groups trained per session ($n = 10$) or a TOTAL, where 1 exercise was performed per muscle group in a session with all muscle groups trained in each session ($n = 10$). All other RT variables (e.g., exercises performed, weekly training volume, rest interval, etc.) were held constant. The training intervention lasted 8 weeks. Testing was carried out pre- and poststudy for maximal muscle strength and hypertrophic adaptations in the forearm flexors (biceps brachii and brachialis), forearm extensors (triceps brachii), and vastus lateralis.

Subjects

Subjects were 20 male volunteers (height = 1.76 ± 0.05 m; body mass = 78.0 ± 10.7 kg; age = 23.5 ± 2.9 years) recruited from a university population. Age range of subjects was 19–29 years. This sample size was justified by a priori power analysis based on previous work from our laboratory using vastus lateralis thickness as the outcome measure with a target effect size difference of 0.6, alpha of 0.05, and power of 0.80. Subjects were well trained; all had been RT a minimum of 3 days-per-week for at least 1 year, with a mean lifting experience of 4.5 ± 3.1 years. Moreover, all subjects regularly performed the barbell back squat and bench press exercises for at least 1 year before entering the study. Subjects were free from any existing musculoskeletal disorders and stated they had not taken anabolic steroids or any other illegal agents known to increase muscle size for the previous year.

Participants were pair matched according to baseline strength and then randomly assigned to 1 of the 2 experimental groups: a SPLIT, where multiple exercises were performed for a specific muscle group in a session with 2–3 muscle groups trained per session ($n = 10$) or a TOTAL, where 1 exercise was performed per muscle group in a session with all muscle groups trained in each session ($n = 10$). Approval for the study was obtained from the Institutional Review Board at Lehman College. Informed consent was obtained from all subjects before participation.

Table 1. Training protocols.

Protocol	Day 1	Day 2	Day 3
SPLIT	Bench press ×3	Squat ×3	Shoulder press ×2
	Incline press ×3	Leg press ×3	Hammer shoulder press ×2
	Hammer chest press ×3	Leg extension ×3	Upright row ×2
	Lat pulldown (wide grip) ×3	Stiff-leg deadlift ×3	Hammer curl ×2
	Lat pulldown (close grip) ×3	Hamstrings curl ×3	Barbell curl ×2
	Seated row ×3	Good morning ×3	Preacher curl ×2
			Cable pushdown ×2
			Skull crusher ×2
			Dumbbell overhead extension ×2
TOTAL	Squat ×3	Leg press ×3	Leg extension ×3
	Stiff-leg deadlift ×3	Hamstrings curl ×3	Good morning ×3
	Bench press ×3	Incline press ×3	Hammer chest press ×3
	Lat pulldown (wide grip) ×3	Lat pulldown (close grip) ×3	Seated row ×3
	Shoulder press ×2	Hammer shoulder press ×2	Upright row ×2
	Hammer curl ×2	Barbell curl ×2	Preacher curl ×2
	Cable pushdown ×2	Skull crusher ×2	Dumbbell overhead extension ×2

Resistance Training Procedures

The RT protocol consisted of 21 exercises targeting the major muscle groups. Subjects were instructed to refrain from performing any additional resistance-type training for the duration of the study. Over the course of each training week, all subjects performed the same exercises and repetition volume throughout the duration of the study. The specific protocols for SPLIT and TOTAL are outlined in Table 1.

The training protocol for both groups consisted of 3 weekly sessions performed on nonconsecutive days for 8 weeks. Subjects performed 2 to 3 sets per exercise for a total of 18 sets per session. Each set involved 8–12 repetitions with 90 seconds of rest afforded between sets. Sets were carried out to the point of momentary concentric muscular failure–the inability to perform another concentric repetition while maintaining proper form. The load was adjusted for each exercise as needed on successive sets to ensure that subjects achieve failure in the target repetition range. Cadence of repetitions was carried out with a controlled concentric contraction and an approximately 2-second eccentric contraction. All routines were directly supervised by research assistants to ensure proper performance of the respective routines. Before training, all subjects underwent 10RM testing to determine individual initial training loads for each exercise. Repetition maximum testing was consistent with recognized guidelines as established by the National Strength and Conditioning Association (3). Attempts were made to progressively increase the loads lifted each week within the confines of maintaining the target repetition range.

Dietary Adherence

To avoid potential dietary confounding of results, subjects were advised to maintain their customary nutritional regimen and to avoid taking any supplements other than that provided during the course of the study. Dietary adherence was assessed by self-reported food records using MyFitnessPal.com (http://www.myfitnesspal.com), which were collected twice during the study: 1 week before the first training session (i.e., baseline) and during the final week of the training period. Subjects were instructed on how to properly record all food items and their respective portion sizes that were consumed for the designated period of interest. Each item of food was individually entered into the program, and the program provided relevant information as to total energy consumption, as well as amount of energy derived from proteins, fats, and carbohydrates for each time period analyzed. In an attempt to maximize tissue anabolism, subjects were provided with a supplement on training days containing 24 g protein and 1 g of carbohydrate (Iso100 Hydrolyzed Whey Protein Isolate; Dymatize Nutrition, Farmers Branch, TX, USA). The supplement was consumed within 1-hour postexercise, as this time frame has been purported to help potentiate increases in muscle protein synthesis (MPS) after a bout of RT (2). Subjects were instructed to avoid consumption of any other muscle-building supplements during the study period.

Table 3. Weekly volume load by muscle group (in kilograms).

Muscle group	Total body	Split body
Chest	5,246 ± 995	4,564 ± 871
Back	5,908 ± 1,121	5,390 ± 781
Anterior thigh	13,335 ± 9,939	10,961 ± 7,317
Posterior thigh	5,469 ± 1,963	5,123 ± 2,357
Shoulders	2,123 ± 405	2,014 ± 462
Forearm flexors	1,501 ± 516	1,468 ± 390
Forearm extensors	2,251 ± 857	2,266 ± 940

Measurements

Muscle Thickness. Ultrasound imaging was used to obtain measurements of MT. The reliability and validity of ultrasound in determining MT is reported to be very high when compared with the "gold standard" magnetic resonance imaging (22). A trained technician performed all testing using a B-mode ultrasound imaging unit (ECO3; Chison Medical Imaging, Ltd, Jiang Su Province, China). The technician applied a water-soluble transmission gel (Aquasonic 100 Ultrasound Transmission gel; Parker Laboratories Inc., Fairfield, NJ, USA) to each measurement site and a 5 MHz ultrasound probe was placed perpendicular to the tissue interface without depressing the skin. When the quality of the image was deemed to be satisfactory, the technician saved the image to hard drive and obtained MT dimensions by measuring the

Table 2. Dietary measures.

	SPLIT initial	SPLIT final	TOTAL initial	TOTAL final
Calories	2,330	2,339	2,548	2,281
Carbohydrate (g)	275	251	244	246
Fat (g)	70	87	112	85
Protein (g)	150	138	141	133

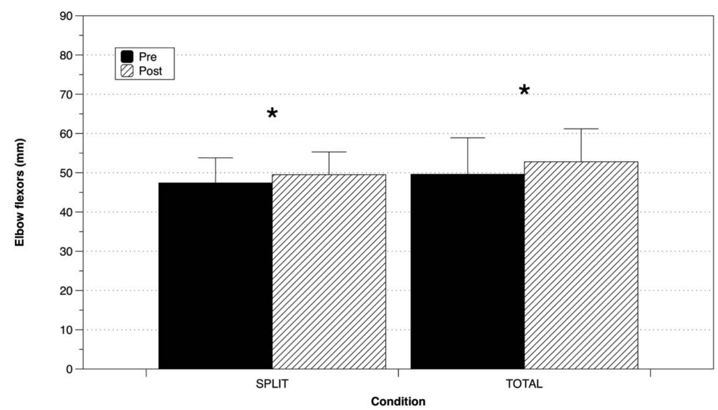

Figure 1. Graphical representation of muscle thickness values of the elbow flexors pre- and postintervention for TOTAL and SPLIT, respectively, mean (±*SD*). Values are expressed in millimeters. *Significantly greater than the corresponding pretraining value.

distance from the subcutaneous adipose tissue-muscle interface to the muscle-bone interface as per the protocol used by Abe et al. (1). Measurements were taken at 3 sites: forearm flexors, forearm extensors, and vastus lateralis. For the anterior and posterior upper arm, measurements were obtained 60% distal between the lateral epicondyle of the humerus and the acromion process of the scapula; for the vastus lateralis, measurements were obtained 50% between the lateral condyle of the femur and greater trochanter. Ultrasound has been validated as a good predictor of muscle volume in these muscles (19,29) and has been used in numerous studies to evaluate hypertrophic changes (1,10,20,21,31). In an effort to help ensure that swelling in the muscles from training did not obscure results, images were obtained 48–72 hours before commencement of the study and after the final training session. This is consistent with research showing that acute increases in MT return to baseline within 48 hours after an RT session (21). The test-retest intraclass correlation coefficient (ICC) values from our laboratory for thickness measurement of the forearm flexors, forearm extensors, and vastus lateralis are 0.986, 0.981, and 0.997, respectively. The *SEM* values for these measures are 0.16, 0.50, and 0.25 mm, respectively.

Muscle Strength. Upper- and lower-body strength was assessed by 1RM testing in the parallel back squat (1RMBS) and bench press (1RMBP) exercises. Subjects reported to the laboratory having refrained from any exercise other than activities of daily living for at least 48 hours before baseline testing and at least 48 hours before testing at the conclusion of the study. Repetition maximum testing was consistent with recognized guidelines as established by the National Strength and Conditioning Association (3). In brief, subjects performed a general warm-up before testing consisting of light cardiovascular exercise lasting approximately 5–10 minutes. A specific warm-up set of the given exercise of 5 repetitions was performed at ~50% 1RM followed by 1 to 2 sets of 2–3 repetitions at a load corresponding to ~60–80% 1RM. Subjects then performed sets of 1 repetition of increasing weight for 1RM determination. A 3- to 5-minute rest was afforded between each successive attempt. All 1RM determinations were made within 5 attempts. Subjects were required to reach parallel in the 1RMBS for the attempt to be considered successful as determined by the research assistants. Successful 1RMBP was achieved if the subject displayed a 5-point body contact position (head, upper back, and buttocks firmly on the bench with both feet flat on the floor) and executed a full lock out. A 1RMBP testing was conducted before 1RMBS with a 5-minute rest

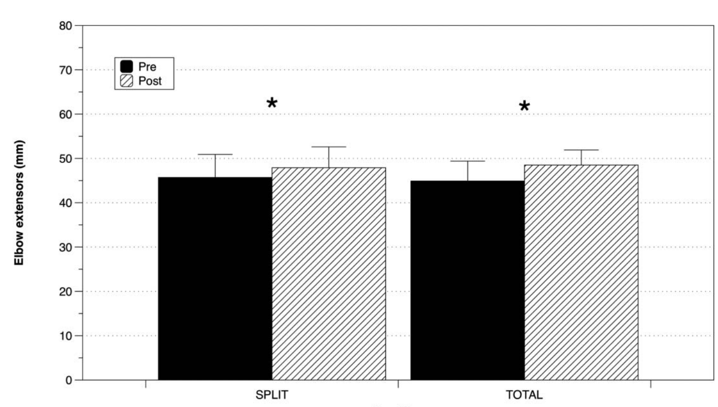

Figure 2. Graphical representation of muscle thickness values of the elbow extensors pre- and postintervention for TOTAL and SPLIT, respectively, mean (±*SD*). Values are expressed in millimeters. *Significantly greater than the corresponding pretraining value.

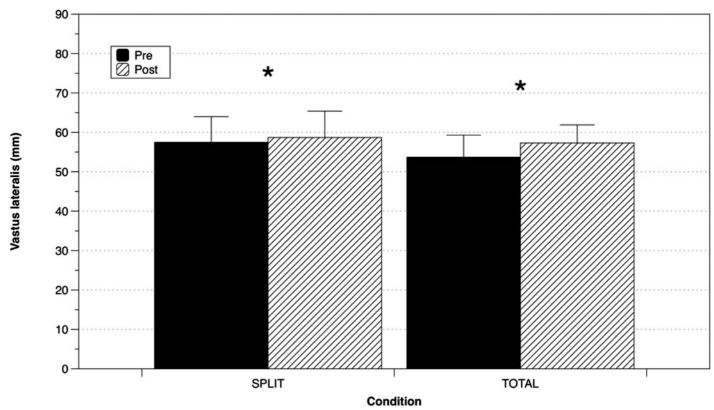

Figure 3. Graphical representation of muscle thickness values of the vastus lateralis pre- and postintervention for TOTAL and SPLIT, respectively, mean (±*SD*). Values are expressed in millimeters. *Significantly greater than the corresponding pretraining value.

period separating tests. Strength testing was carried out using free weights. Recording of foot and hand placement was made during baseline 1RM testing and then used for poststudy performance. All testing sessions were supervised by 2 fitness professionals to achieve a consensus for success on each attempt. The test-retest ICC values for the 1RMBP and 1RMBS from our laboratory are 0.995 and 0.998, respectively. The *SEM* values for these measures are 1.03 and 1.04 kg, respectively.

Statistical Analyses

Descriptive statistics were used to explore the distribution, central tendency, and variation of each measurement. Descriptive statistics (mean ± *SE*) for each variable were reported at baseline, at 8 weeks, and as percent change from baseline. First, we conducted 1-sample *t*-tests to determine whether there were differences between baseline and postintervention outcomes (i.e., $H_0 = 0$ or no differences) within subjects, for both absolute and relative changes. To test differences between groups, we incorporated separate multiple linear regression analyses with postintervention outcomes as the dependent variable and baseline values as covariates. The model included a group indicator with 2 levels and baseline as predictors. This model is equivalent to an analysis of covariance but has the advantage of providing estimates associated with each group, adjusted for baseline characteristics that are potentially associated with changes in the outcomes. This was also important because of the fact that using change scores as the dependent variable is subject to regression to the mean. As noted by Vickers and Altman (p. 1123) (26), "analyzing change does not control for baseline imbalance because of regression to the mean: baseline values are negatively correlated with change because subjects with low scores at baseline generally improve more than those with high scores." Despite a fairly homogeneous sample, there was *some* variability in both strength and MT at baseline. Thus, we decided to incorporate this statistical technique to ameliorate the influence of such imbalances. Each model therefore included a group indicator with 2 levels (0 and 1), as well as baseline values as predictors. Regression assumptions were checked and fulfilled. An independent *t*-test was used to compare volume-load between groups. 2-tailed alpha was set at 0.05.

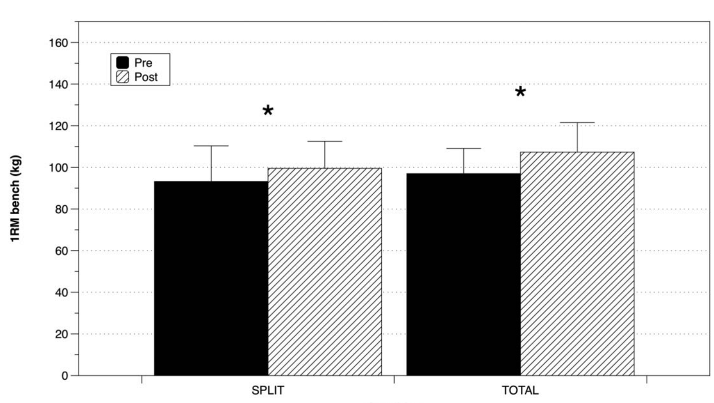

Figure 4. Graphical representation of 1 repetition maximum bench press values pre- and postintervention for TOTAL and SPLIT, respectively, mean (±*SD*). Values are expressed in kilograms. *Significantly greater than the corresponding pretraining value.

Results

Nineteen subjects completed the study (10 in the TOTAL group and 9 in the SPLIT group); 1 subject dropped out for personal reasons. Adherence to both the TOTAL and

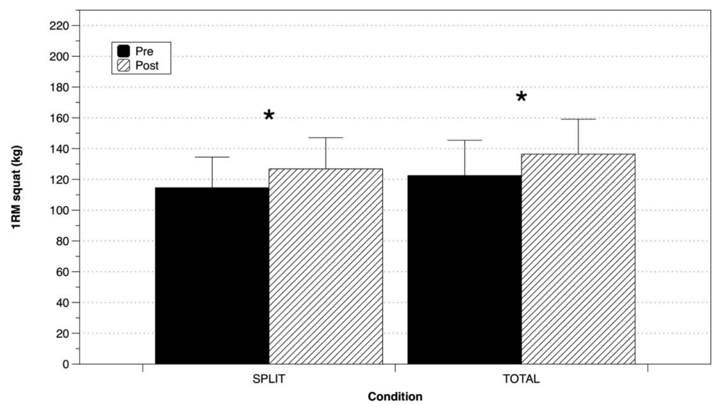

Figure 5. Graphical representation of 1 repetition maximum back squat values pre- and postintervention for TOTAL and SPLIT, respectivley, mean (±*SD*). Values are expressed in kilograms. *Significantly greater than the corresponding pretraining value.

SPLIT protocols was excellent (97 and 98% attendance, respectively). The TOTAL group was significantly taller than SPLIT; no other baseline differences were noted between groups. There were no differences in any dietary measure either within- or between-subjects over the course of the study (Table 2). There were no differences in weekly volume load between conditions for any of the muscle groups trained (Table 3).

Muscle Thickness

Ultrasound imaging of the forearm flexors showed that both the TOTAL and SPLIT groups increased MT from baseline to poststudy by 3.2 mm (6.5%) and 2.1 mm (4.4%), respectively (all $p < 0.001$) (Figure 1). When adjusting for baseline, a significant difference was noted such that TOTAL produced superior results compared with SPLIT ($\beta = 1.41$; $p = 0.012$).

Ultrasound imaging of the forearm extensors showed that both the TOTAL and SPLIT groups increased MT from baseline to poststudy by 3.6 mm (8.0%) and 2.3 mm (5.0%), respectively (all $p < 0.001$) (Figure 2). No significant between-group differences were noted for absolute or relative change nor when adjusted for baseline triceps thickness ($\beta = 1.10$; $p = 0.24$).

Ultrasound imaging of the vastus lateralis showed that both the TOTAL and SPLIT groups increased MT from baseline to poststudy by 3.6 mm (6.7%) and 1.2 mm (2.1%), respectively (all $p \leq 0.05$) (Figure 3). No significant between-group differences were noted for absolute or relative change nor when adjusting for baseline ($\beta = 1.86$; $p = 0.08$).

Maximal Strength

Both groups showed a significant increase in 1RMBP from baseline to poststudy by 10.2 kg (10.6%) ($p < 0.01$) and 6.3 kg (6.8%) (all $p \leq 0.05$) for TOTAL and SPLIT, respectively (Figure 4). No significant between-group differences were noted for absolute or relative change nor when adjusting for baseline ($\beta = 9.87$; $p = 0.14$).

Both groups showed a significant increase in 1RMBS from baseline to poststudy by 13.8 kg (11.3%) ($p < 0.01$) and 12.1 kg (10.6%) ($p \leq 0.05$) for TOTAL and SPLIT, respectively (Figure 5). No significant between-group differences were noted for absolute or relative change nor when adjusting for baseline ($\beta = 4.65$; $p = 0.52$).

Discussion

This is the first study to our knowledge that directly assesses the hypertrophic response to different RT frequencies. Our novel findings suggest a hypertrophic benefit to higher frequencies of training when volume is equated between conditions. Specifically, a significantly greater increase in MT of the forearm flexors was demonstrated in TOTAL compared with SPLIT (6.5 vs. 4.4%, respectively). Although forearm extensor MT was not statistically different between groups, the effect size for TOTAL was 96% greater than that of SPLIT (0.90 vs. 0.46, respectively). Similarly, the effect size for quadriceps thickness markedly favored the higher frequency protocol (0.70 vs. 0.18, respectively). In combination, these data provide evidence that well-trained individuals benefit from including periods of training muscle groups 3 days-per-week when the goal is to maximize muscle hypertrophy. Results are consistent with the time course of MPS, which has been shown to last approximately 48-hour post-RT (16). Theoretically, keeping MPS consistently elevated over the course of each week would heighten myofibrillar protein accretion and thus have a positive effect on muscle size.

On a percentage basis, an advantage was seen for TOTAL compared with SPLIT with respect to increases in 1RMBP (10.6 vs. 6.8%, respectively) and 1RMBS (11.3 vs. 10.6%, respectively). However, results were not significantly different between conditions. Effect sizes for 1RMBP favored TOTAL compared with SPLIT (0.57 vs. 0.41, respectively), suggesting a meaningful difference in results. Effects sizes for 1RMBS were identical between groups.

Only a few controlled trials have investigated the effects of frequency of RT on muscular adaptations. In a study comparing 1 vs. 3 days a week of volume-equated RT in well-trained subjects, McLester et al. (17) reported that strength gains in the lower frequency condition were less than 2/3 that of the higher frequency condition after 12 weeks of RT. Moreover, percent change differences for lean body mass accretion favored the high- vs. low-frequency condition (~8 vs. ~1%, respectively), although results were not statistically significant. Conversely, Candow and Burke (4) investigated the effects of training 2 vs. 3 days a week in a cohort of untrained men and women. After 6 weeks, no differences in muscle strength or lean tissue mass (as assessed by DXA) were seen between conditions. The apparent discrepancies between these studies may be related to the training status of the participants. Subjects in the McLester et al. (17) study were experienced with RT, whereas those in Candow and Burke (4) were novice lifters. It is conceivable that early-phase adaptations are less sensitive to alterations in frequency and that benefits manifest as an individual becomes progressively more trained. Indeed, a meta-analysis by Rhea et al. (23) found that well-trained individuals required a greater number of weekly training sessions to maximize strength gains compared with their untrained counterparts. Moreover, the lower frequency condition in the McLester et al. (17) study trained only once per week, whereas those in Candow and Burke (4) trained twice weekly. This raises the possibility that a threshold is reached by training 2 times per week and that further increases in frequency may not yield additional benefits.

Our study expands on previous findings by providing direct evidence of greater site-specific increases in MT with higher weekly RT frequencies in well-trained men. With respect to muscular strength, our findings were similar to those of McLester et al. (17) in the 1RMBP, with SPLIT achieving approximately 2/3 the gains of TOTAL. Alternatively, no differences in 1RMBS were noted in our study. The discrepancies in findings may potentially be attributed to differences in study designs. McLester et al. (17) used the same exercises each training session and subjects were tested on these exercises pre- vs. poststudy. However, our study was designed to mimic the typical SPLITss used by fitness enthusiasts and thus exercises for each muscle group were rotated on a session-to-session basis each week. The greater effect sizes in 1RMBP for TOTAL vs. SPLIT may be related to the fact that the additional exercises performed for the chest musculature all had similarities to the bench press (incline bench press and Hammer Strength chest press). The specificity of these exercises to the bench press would conceivably provide greater transfer of training from a neuromuscular standpoint, which has been shown to be critical to maximal increases in strength (5,6). In contrast, there would appear to be less specificity for the machine-based lower-body exercises included in the protocol (leg press and leg extension) to the squat, which may have diminished the neural advantage of the increased training frequency in TOTAL.

Although this study suggests that total-body workouts enhance muscular adaptations in well-trained individuals, the results do not necessarily imply that a split routine is without merit. Our study sought to equate volume between conditions in an effort to control for the effects of frequency on muscular adaptations. However, given that training different muscle groups on different days is thought to be less energetically taxing than full-body workouts, a split routine provides a practical means to perform a higher training volume per muscle group while maintaining intensity of effort and providing adequate recovery between sessions (11). A clear dose-response relationship has been shown between RT volume and muscular adaptations at least up to a certain threshold (14,15). Thus, implementation of a split routine may be an effective strategy to enhance hypertrophic increases by facilitating the use of higher volumes over time. This hypothesis warrants further investigation.

Our study had several limitations that must be considered when attempting to draw evidence-based inferences. First, the study period lasted only 8 weeks. Although this duration was sufficient to achieve significant increases in muscular strength and hypertrophy in both groups, it is conceivable that results between groups would have diverged over a longer time frame.

Second, measurements of MT were obtained only at the middle portion of the muscle. Although this region is often used as a proxy of overall growth of a given muscle, research indicates that hypertrophy manifests in a regional-specific manner, with greater gains sometimes seen at the proximal and distal aspects (27,28). Proposed mechanisms for this phenomenon include exercise-specific intramuscular activation and tissue oxygenation saturation (18,27,28). The possibility therefore exists that differential changes in proximal or distal MT may have occurred in 1 condition vs. the other, which would have gone undetected in our protocol.

Third, the novelty factor of changing programs may have unduly influenced results. During prestudy interviews, 16 of the 19 subjects reported training with a split routine on a regular basis. Although the topic has not been well studied, there is some evidence to indicate that muscular adaptations are enhanced when program variables are altered outside of traditional norms (12). Thus, it is conceivable that those in TOTAL benefited from the unaccustomed stimulus of training more frequently. Future research should endeavor to include an indoctrination phase before the start of the actual study where subjects are exposed to the intended stimulus for a period of time that sufficiently acclimates the neuromuscular system to greater training frequencies. It also is possible that periodizing training frequencies might provide a means to maintain novelty of the stimulus and thus promote continued gains over time. This hypothesis warrants further investigation.

Fourth, the small sample size affected statistical power. A high degree of interindividual variability was noted between subjects, which limited the ability to detect significant differences in several outcome measures. Despite this limitation, analysis of effect sizes and statistical trends provide a good basis for drawing inferential conclusions from the results.

Finally, findings of our study are specific to young resistance-trained men and therefore cannot necessarily be generalized to other populations including adolescents, women, and the elderly. It is possible that higher RT frequencies may not be as well tolerated in these individuals and perhaps could hasten the onset of overtraining when combined with a high intensity of effort. Future research is required to determine the frequency-related responses to RT across populations.

Practical Applications

This study suggests the existence of a dose-response relationship between RT frequency and muscular adaptations. It is conceivable that optimal hypertrophic benefits could be obtained by periodizing frequency over the course of a long-term training cycle. Such a strategy would maintain the novelty of the training stimulus and thus allow continual increases in accretion of muscle contractile proteins.

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