# A Comparison Between Total Body and Split Routine Resistance Training Programs in Trained Men

**Sandro Bartolomei,[1] Federico Nigro,[2] Ivan Malagoli Lanzoni,[2] Federico Masina,[2] Rocco Di Michele,[1] and Jay R. Hoffman[3]**

*[1]Department of Biomedical and Neuromotor Sciences, University of Bologna, Bologna, Italy; [2]Department for Life Quality Studies, University of Bologna, Bologna, Italy; and [3]Department of Molecular Biology, Ariel University, Ariel, Israel*

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**Abstract**

Bartolomei, S, Nigro, F, Malagoli Lanzoni, I, Masina, F, Di Michele, R, and Hoffman, JR. A comparison between total body and split routine resistance training programs in trained men. *J Strength Cond Res* 35(6): 1520–1526, 2021—The purpose of the present investigation was to compare the effects of total body (TB) versus split routine (SR) resistance training workouts on maximal strength and muscle hypertrophy in trained men. Twenty-one resistance-trained men were randomly assigned to either a TB (TB: age = 24.1 ± 4.4 years; body mass = 78.7 ± 11.3 kg; body height = 177.0 ± 3.9 cm) or the SR group (SR: age = 24.9 ± 4.2 years; body mass = 79.2 ± 9.5 kg; body height = 175.2 ± 6.0 cm). Both groups performed a 10-week resistance training program. Isokinetic bench press at 75 and 25 cm·s$^{-1}$ (ISOK75 and ISOK25, respectively), isometric bench press (ISOBP), isometric squat (ISOSQ), and one repetition maximum BP and SQ assessments were performed before and after training. Muscle thickness of the pectoralis major (PECMT), superior part of trapezius (TRAPMT), and vastus lateralis (VLMT) muscles was also evaluated at the same timepoints using ultrasonography. Improvements were observed in both groups for all strength assessments and muscle thicknesses. Only changes in ISOK25 were significantly ($p = 0.015$) greater in TB than in SR, while significantly greater ($p = 0.037$) changes in VLMT were detected in SR compared with TB. Results indicated that a TB training paradigm may be more appropriate for maximal strength improvement, while an SR training protocol may be more optimal in stimulating muscle growth in experienced, resistance-trained men.

**Key Words:** strength, ultrasound, training load, force plates

## Introduction

Training frequency is generally defined as the number of workouts performed within a week (34). In resistance training, however, training frequency may also refer to the number of times a specific muscle group is trained per week (32). This parameter is influenced by the number of resistance training workouts per week and by the number of muscle groups exercised during each training session. Total body (TB) and split routine (SR) training paradigms represent 2 of the most common approaches to organizing resistance training workouts (32). A TB training program is characterized by a workout that includes exercises for all muscle groups, while an SR training program focuses on exercising only specific muscle groups (e.g., chest, shoulders, and triceps). The SR training program generally uses several exercises for each specific muscle group and trains each muscle group either once or twice per week (12).

Both training paradigms are used by strength/power athletes and sport enthusiasts; SR, however, is more common than TB among advanced bodybuilders (19), whereas TB is more popular among weightlifters (11,13). Previous research has also indicated that the use of an SR training program may be more beneficial for strength development than a TB workout by allowing a greater number of assistance exercises to be performed per workout (21). The increase in the number of assistance exercises seems to be an important stimulus for increasing strength in experienced, resistance-trained strength/power athletes (21). However, some coaches consider the TB approach a more appropriate training method for their athletes (7,33). The rationale behind the TB training paradigm is that performing a few exercises for each muscle group will allow the athlete to maintain a greater training intensity. Some investigators suggest that a high training frequency may stimulate greater elevations in protein synthesis in trained individuals (9). In addition, multiple exercises performed with the same muscle group may reduce total training volume (TTV) due to excessive fatigue. By contrast, the SR training paradigm provides a considerable amount of time between same muscle group workouts (e.g., 72 hours), allowing for sufficient recovery between training sessions (34).

Several studies have compared TB and SR strategies in various populations (5,31,32). In one investigation examining experienced, resistance-trained men, no differences were noted in muscle hypertrophy between a powerlifting-style TB program and a bodybuilding-style SR after 8 weeks of training (31). The TB group, however, experienced greater improvements in maximal strength. This may have been related to the greater training intensity observed in the TB compared with the SR group. Both training programs were volume-equated, but training schemes were different in regards to training intensity and recovery time between sets. More recently, the same investigative team (32) reported superior gains in muscle hypertrophy after a TB scheme

*Address correspondence to Dr. Sandro Bartolomei, sandro.bartolomei@unibo.it.*



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compared with SR when the training intensity was equated. However, the latter study reported no significant differences in strength gains between the 2 training paradigms. Both investigations examined experienced, resistance-trained men, with 4.2 and 4.5 years of training experience, respectively. In the latter study (32), both the TB and SR training programs required subjects to perform a total of 18 sets of 8–12 repetitions during each of the 3 training sessions per week. However, bodybuilders and strength athletes often perform a considerably greater number of sets per workout and participate in more training sessions per week (1) resulting in a greater training volume.

Other scientific studies (6,26) have used previously untrained individuals participating in a lower frequency of training (2–3 days) per week. Training adaptations are likely influenced by the training experience of the subjects, frequency of training, and the TTV of the workout (18). The limitations of the aforementioned studies make it difficult to draw conclusions about the superiority of either TB or SR approach in resistance-trained men after a heavy-resistance training program. Thus, the purpose of the present investigation was to compare the effects of a 10-week TB or SR resistance training program on maximal strength and muscle hypertrophy in resistance-trained men. It was hypothesized that TB may elicit greater gains than SR on maximal strength and muscle hypertrophy by maintaining training intensity and stimulating protein synthesis (9).

## Methods

### Experimental Approach to the Problem

Subjects were randomly assigned to either a TB or SR training group. Both groups performed a 10-week training program using the same exercises and the same total number of repetitions per set. During each training session, subjects in the TB group performed exercises recruiting muscle groups of both the upper and lower body, while subjects in the SR group performed a training program involving a limited number of muscle groups per training session. Specifically, the SR training group trained the chest and triceps on Monday, the legs on Tuesday, the back and biceps on Thursday, and the shoulders on Friday. Subjects were assessed for upper- and lower-body maximal strength before (PRE) and after (POST) the 10-week training program. POST assessments were performed 72 hours after the last training session. Measurements of muscle architecture and body composition were also collected at the same assessment periods.

### Subjects

Twenty-one experienced, resistance-trained men were randomly assigned to either a TB group (mean ± *SD*; TB group: $n = 10$; age = 24.1 ± 4.4 years; body mass = 78.7 ± 11.3 kg; body height = 177.0 ± 3.9 cm; body fat = 10.4 ± 1.8%) or an SR training group (SR group: $n = 11$; age = 24.9 ± 4.2 years; body mass = 79.2 ± 9.5 kg; body height = 175.2 ± 6.0 cm; body fat = 12.3 ± 3.5%). Inclusion criteria required subjects to have performed resistance training at least 3 times per week for at least 3 years (mean ± *SD* = 6.6 ± 3.5 years of training experience) and were familiar with both powerlifting and weightlifting exercises. Subjects were not permitted to use any dietary supplementation and reportedly did not consume any androgens or other performance-enhancing drugs. Screening for performance enhancing drug use and additional supplementation was accomplished through a health questionnaire completed at the recruitment stage. All subjects were between the age of 18 and 35 years and signed an informed consent document after being informed about the risks and benefits of the study. Exclusion criteria included injuries occurred in the year before the study. Subjects were asked to abstain from alcohol, caffeine and resistance training for at least 24 hours before all assessments. The study was approved by the University of Bologna Review Board.

### Procedures

Anthropometric evaluations were performed before the first assessment session. Body measurements included body mass, height, and body fat. Body mass was measured to the nearest 0.1 kg (Seca 769, Seca Scale Corp., Munich, Germany). Body fat percentage was estimated from skinfold caliper measures using the method of Evans et al. (10). The same investigator performed all skinfold analysis assessments. Before the strength and power assessments, subjects performed a standardized warm-up consisting of 5 minutes on a cycle ergometer against a light resistance, 10 body weight squats, 10 body weight walking lunges, 10 dynamic walking hamstring stretches, 10 dynamic walking quadriceps stretches, and 5 push-ups.

*Strength Assessments.* Isokinetic bench press strength measurements were performed using a linear isokinetic dynamometer (Lido Loredan Linea, Shirley, NY). Subjects were positioned with their elbows at 90° of flexion while laying in supine position on a bench, and their grip width was measured and recorded. Isokinetic concentric measurements were performed at a velocity of 75 $cm \cdot s^{-1}$ (ISOK75) and 25 $cm \cdot s^{-1}$ (ISOK25). Subjects performed 2 trials at each velocity with a 3-minute recovery time between trials. The best performance was recorded. Intraclass coefficients were 0.90 (*SEM* = 37.8 N) and 0.92 (*SEM* = 39.5 N) for ISOK75 and ISOK25, respectively.

An isometric bench press (ISOBP) assessment, as previously described by Bartolomei et al. (3), was performed using a power rack that permitted fixation of the bar. The bench was positioned over a force plate (Kistler 9260, 500 Hz; Kistler A.G., Winterthur, Switzerland). Subjects were required to position themselves on the bench with their elbows at 90° of flexion and with their feet up on the edge of the bench. Elbow angle and grip width were measured to reproduce the same position for all testing sessions. Subjects were asked to press against the bar as hard as possible for 6 seconds. The force expressed against the bar was transmitted by the bench to the force plate, and peak force was calculated. The same adjustable rack and force plate were used for the isometric half squat (ISOSQ). The isometric half squat was performed at a knee flexion angle of 90° between the femur and the tibia with hip flexion at 90°. Both angles were measured at the beginning of the test using a goniometer. Subjects were required to perform 2 maximal 6-s isometric contractions in both ISOBP and ISOSQ with a 3-minute recovery time between each attempt. For both ISOBP and ISOSQ, peak force was measured. Before the first maximum effort trial in both isometric and isokinetic assessments, subjects were asked to perform 2 submaximal trials. Intraclass coefficients were 0.85 (*SEM* = 267.1 N) and 0.83 (*SEM* = 219.6 N) for ISOBP and ISOSQ, respectively.

Subjects reported back to the laboratory the following day and performed one repetition maximum (1RM) strength test in the parallel squat (SQ) and bench press (BP) exercises using the method previously described by Hoffman (20). The same warm-up previously described was performed by the subjects before the 1RM test. During the 1RMSQ, subjects were asked to reach



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**Table 1**
**Exercise distribution in total body training program (5 sets of 6 reps, 1 repetition in reserve, in each exercise).**

| Monday | Tuesday | Thursday | Friday |
|---|---|---|---|
| Bench press | Deadlift | Deep squat | Reverse barbell rows |
| Parallel squat | Military press | Inclined bench press | Dumbbell bench press |
| Lat machine | Prone lateral raises | Pulley row | Stiffed-leg deadlift |
| Behind neck shoulder press | Lunges | Lateral raises | Dumbbell shoulder press |
| Front raises | High pull | Pull-ups | Leg curl |
| Barbell biceps curls | Skull crusher | Scott-bar biceps curl | Triceps extension |
| | Leg extension | Standing calf raises | |

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a position where the greater trochanter of the femur was at the same level of the knee. An investigator monitored the subject's technique while another researcher monitored the depth of the squat. In the 1RMBP, a flat-back technique with feet on the ground was used, and subjects were required to lower the bar to their chest before initiating the concentric movement. A 3-minute recovery time was observed between 1RM attempts. In both 1RMSQ and 1RMBP, subjects were required to reach their maximum load within 5 attempts. During all strength measurements, subjects were verbally encouraged by the study investigators. All subjects were familiar with the assessments performed in the investigation.

*Ultrasonography Measurements.* Noninvasive skeletal muscle ultrasound images were collected from the subject's right side of the body. Before image collection, all anatomical locations of interest were identified using standardized landmarks for the vastus lateralis (VL), pectoralis major (PEC), and trapezius (TRAP). The landmark for the VL was identified along its longitudinal distance at 50% from the proximal insertion of the muscle. The length of the VL encompassed the distance from the lateral condyle of the tibia to the most prominent point of the greater trochanter of the femur (4). Vastus lateralis muscle thickness (VLMT) and VL pennation angle (VLPA) measurements required the subject to lay on their side on the examination table with a 10° bend angle in the knees for a minimum of 15 minutes before images were collected. Muscle thickness of the pectoralis (PECMT) was measured at the site between third and fourth costa under the clavicle midpoint (36). Muscle thickness of the trapezius (TRAPMT) was measured at the midpoint of the muscle belly between T1 and the posterior acromial edge, where the muscle borders were parallel (27). The same investigator, blinded to treatment allocation, performed all landmark measurements for each subject. Ultrasonography measurements were taken 72 hours after the last training session.

A 12-MHz linear probe scanning head (Echo Wave 2; Telemed Ultrasound Medical System, Milan, Italy) was coated with water-soluble transmission gel to optimize spatial resolution and used to collect all ultrasound images. The probe was positioned on the surface of the skin without depressing the dermal layer, and the view mode (gain = 50 dB; image depth = 5 cm) was used to take pictures of the muscle. All images were taken and analyzed by the same technician. Muscle thickness and VLPA were quantified in still images using the measuring features of the ultrasound device. MT was determined as the distance between subcutaneous adipose tissue–muscle interface and intermuscular interface, and VLPA was determined as the angles between the echoes of the deep aponeurosis of the muscle and the echoes from interspaces among the fascicles. Intraclass correlation coefficients were 0.96 (*SEM* = 0.63 mm) and 0.93 (*SEM* = 1.1°) for VLMT and VLPA, respectively. Intraclass coefficients were 0.96 (*SEM* = 0.93 mm) and 0.95 (*SEM* = 1.05 mm) for TRAPMT and PECMT, respectively.

*Training Protocols.* The 10-week resistance training program for the TB and SR groups can be seen in Table 1 and Table 2, respectively. All subjects exercised 4 days per week, and the exercises performed were the same for each group. The groups differed only in the distribution of the exercises within the training days. In TB, each training session involved all muscle groups, whereas in SR, each training session was focused on a single muscle group. Subjects were asked to perform 5 sets of 6 repetitions for each exercise, with a 2-minute rest time between sets. Intensity was selected because the load allowing the subject to perform 6 repetitions without reaching volitional failure, with one repetition in reserve (1-RIR) (35).

Subjects were encouraged to increase the resistance used per workout if they were able to perform the required number of repetitions. Subjects recorded all workouts in a logbook, which was collected by one of the investigators after each workout. All training sessions were supervised by certified investigators. The TTV was calculated for each subject based on the total load lifted in each workout and for each week. To avoid the potential ergogenic effect of music (2), subjects were not allowed to listen to music during either the resistance training or testing sessions.

**Table 2**
**Exercise distribution in split routine training program (5 sets of 6 reps, 1 repetition in reserve, in each exercise).**

| Monday | Tuesday | Thursday | Friday |
|---|---|---|---|
| Bench press | Parallel squat | Deadlift | Military press |
| Inclined bench press | Lunges | Reverse barbell rows | High pull |
| Dumbbell bench press | Stiffed-leg deadlift | Prone lateral raises | Dumbbell shoulder press |
| Triceps extension | Leg extension | Lat machine | Behind neck shoulder press |
| Skull crusher | Leg curl | Pulley row | Lateral raises |
| | Deep squat | Pull ups | Front raises |
| | Standing calf raises | Barbell biceps curl | |
| | | Scott-bar biceps curl | |



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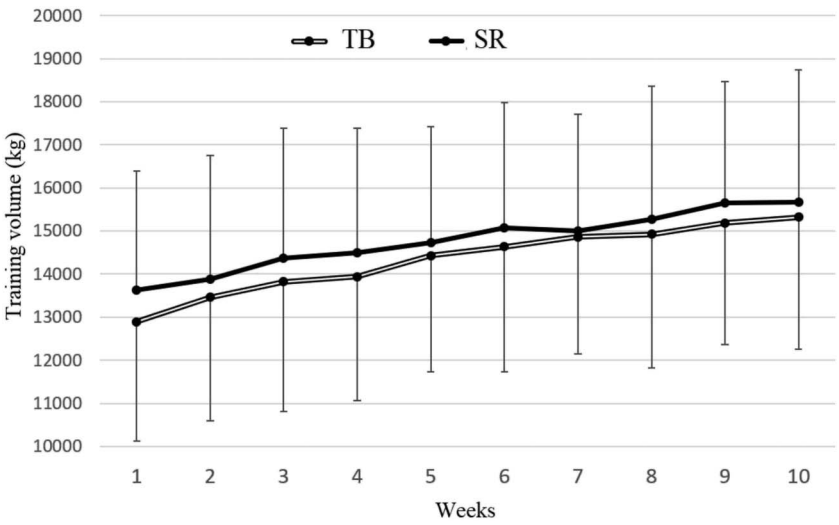


**Figure 1.** Training volume for both the TB and SR groups during the training period. SR = split routine; TB = total body.

### *Statistical Analyses*

A Shapiro–Wilk test was used to assess the normal distribution of the data. Data were statistically analyzed using separate 1-way analysis of covariance for anthropometric and performance measures. The pre-test and the post-test values were used as covariate and dependent variable, respectively. In addition, TTV performed by each group during the 10-week programs was compared using an independent *t* test. An alpha level of $p \leq 0.05$ was used to determine statistical significance. In a separate analysis, mean percentage change values ([POST mean − PRE mean]/[PRE mean] × 100) were evaluated with 95% confidence intervals. All data are reported as mean ± *SD*. For effect size, the partial eta-squared ($\eta^2$) statistic was reported, and according to Green et al. (17), 0.01, 0.06, and 0.14 represent small, medium, and large effect sizes, respectively.

## Results

### *Performance Assessments*

Total training volume for both the TB and SR groups are depicted in Figure 1. The analysis of covariance (ANCOVA) did not indicate a significant difference ($F = 0.545$; $p = 0.471$; $\eta^2 = 0.033$; CI 95%, −739.96 to −1,530.47) after adjusting for pre-test differences between the groups for the total load lifted between the first and 10th week of the training program. No significant differences were noted between TB and SR on TTV ($p = 0.576$; CI 95%, −39,177.48 to 22,564.98; average = 143,480 ± 33,713 kg and 147,762 ± 28,194 kg, respectively).

Results of the performance assessments and percent change in strength performance for both TB and SR are reported in Table 3 and Figure 2, respectively. The 2 groups differed significantly ($F = 7.459$; $p = 0.015$; $\eta^2 = 0.318$; CI 95%, 2.73–21.73) on post-test scores after adjusting for the pre-test scores for ISOK25. An 11.5% increase was observed in ISOK25 for TB from pre to post, while an increase of 2.3% was noted for SR. No significant differences were noted between TB and SR for ISOK75 ($F = 0.098$; $p = 0.758$; $\eta^2 = 0.006$; CI 95%, −5.66 to 7.63), ISOBP ($F = 0.207$; $p = 0.605$; $\eta^2 = 0.013$; CI 95%, −102.03 to 157.81), or ISOSQ ($F = 0.640$; $p = 0.435$; $\eta^2 = 0.038$; CI 95%, −71.71 to 158.67). In addition, no significant group differences were observed for either 1RMSQ or 1RMBP ($F = 1.150$; $p = 0.303$; $\eta^2 = 0.081$; CI 95%, −5.17 to 16.98 and $F = 0.126$; $p = 0.728$; $\eta^2 = 0.010$; CI 95%, −8.45 to 6.08, respectively).

### *Muscle Morphology Assessments*

Results of muscle morphology and percent change in muscle architecture assessments are reported in Table 4 and Figure 3, respectively. A significant difference between the groups after

**Table 3**

**Results of the performance assessments pre and post the 10-week training program in the TB and SR groups.***

| Assessment | TB group | SR group | Group difference |
|---|---|---|---|
| ISOK75 (N) | | | |
| Pre | 745.6 ± 135.8 | 783.2 ± 93.4 | $F = 0.098$ |
| Post | 785.4 ± 146.1 | 813.7 ± 118.6 | $p = 0.758$ |
| | | | $\eta^2 = 0.006$ |
| ISOK25 (N) | | | |
| Pre | 1,030.9 ± 217.0 | 1,106.4 ± 183.6 | $F = 7.459$ |
| Post | 1,164.8 ± 285.7 | 1,132.0 ± 208.7 | $p = 0.015$ |
| | | | $\eta^2 = 0.318$ |
| ISOBP (N) | | | |
| Pre | 1,862.1 ± 397.5 | 2,052.0 ± 375.8 | $F = 0.207$ |
| Post | 1,970.6 ± 463.1 | 2,128.6 ± 329.5 | $p = 0.605$ |
| | | | $\eta^2 = 0.013$ |
| ISOSQ (N) | | | |
| Pre | 2,065.9 ± 403.5 | 2,238.8 ± 378.7 | $F = 0.640$ |
| Post | 2,191.2 ± 471.3 | 2,328.8 ± 376.6 | $p = 0.435$ |
| | | | $\eta^2 = 0.038$ |
| 1RMBP (kg) | | | |
| Pre | 92.8 ± 25.1 | 99.0 ± 22.2 | $F = 0.126$ |
| Post | 104.9 ± 27.2 | 111.0 ± 19.5 | $p = 0.728$ |
| | | | $\eta^2 = 0.010$ |
| 1RMSQ (kg) | | | |
| Pre | 114.3 ± 31.8 | 114.0 ± 25.5 | $F = 1.150$ |
| Post | 141.4 ± 33.9 | 135.1 ± 27.5 | $p = 0.303$ |
| | | | $\eta^2 = 0.081$ |

*TB = total body; SR = split routine; ISOK75 = isokinetic bench press at 75 cm·s$^{-1}$; ISOK25 = isokinetic bench press at 25 cm·s$^{-1}$; ISOBP = isometric bench press; ISOSQ = isometric squat, 1RMBP = 1RM bench press; 1RMSQ = 1RM squat; RM = repetition maximum.



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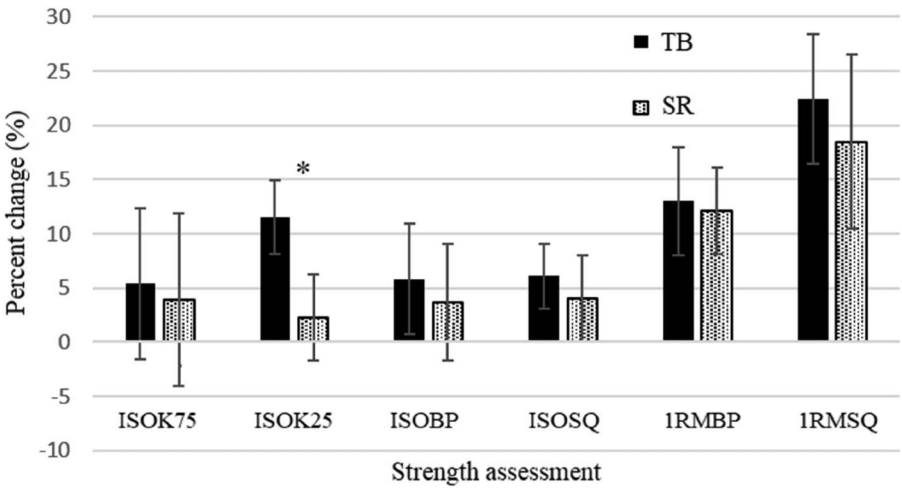


**Figure 2.** Percentage changes in strength assessments from pre to post the 10-week training program in both the TB and SR groups. *Significant difference between the TB and SR groups. SR = split routine; TB = total body; 1RMBP = bench press 1RM; 1RMSQ = squat 1RM; ISOK75 = isokinetic force at 75 cm·s$^{-1}$; ISOK25 = isokinetic force at 25 cm·s$^{-1}$; ISOBP = isometric bench press; ISOSQ = isometric squat; RM = repetition maximum.

adjusting for pre-test differences was noted for VLMT ($F$ = 5.185; $p$ = 0.037; $\eta^2$ = 0.245; CI 95%, −2.20 to −0.08). A 10.0% increases in VLMT was observed in the SR group from pre to post, while a 2.9% increase was detected in the TB group. No significant differences between the 2 groups were noted for either PECMT ($F$ = 0.006; $p$ = 0.939; $\eta^2$ = 0.001; CI 95%, −1.64 to 1.52) or TRAPMT ($F$ = 1.326; $p$ = 0.266; $\eta^2$ = 0.077; CI 95%, −1.70 to 0.52). No significant group differences ($F$ = 0.056; $p$ = 0.815; $\eta^2$ = 0.004; CI 95%, −1.90 to 1.52) were detected for VLPA.

## Discussion

This study investigated the effects of 2 strength training programs using the same exercises and characterized by the same total number of repetitions, on maximal strength and muscle size in experienced, resistance-trained men. Training volume was similar between the 2 groups during the 10-week study, indicating that the 2 training programs were equated for training volume. This likely contributed to the similar performance gains seen in both SR and TB.

Increases in maximal strength were observed in ISOBP, ISOSQ, ISOK75 BP, 1RMBP, and 1RMSQ for both groups, with no group differences noted. The only between-group difference was observed in isokinetic strength expressed at 25 cm·s$^{-1}$, in which significantly greater increases were noted for TB compared with SR for ISOK25; +11.5% and +2.3% in TB and SR, respectively. Greater increases in slow-speed isokinetic strength for TB may be related to the greater frequency of neuromuscular stimulation in this group compared with SR. The small changes in ISOK75 observed from pre- to post-training (+5.3% and +3.8% in TB and SR, respectively) may be related to the absence of high-speed power training and explosive movements in the training programs (20,23).

In this study, the SR program seemed to provide a greater stimulus for muscle hypertrophy of the VL than TB. Although no other significant differences were seen, trends toward greater gains were noted for TRAPMT in SR (+14.6%) compared with TB (+8.3%). The results of this study are not supportive of the recent study by Schoenfeld et al. (32) who reported greater muscle hypertrophy from TB training programs. Several investigators have suggested that high training frequencies may lead to greater strength gains, but only when higher training frequencies were associated with greater training volumes (18,30). Training volume, and not training frequency, has been reported to be a more important factor contributing to increases in muscular strength (28). However, in this study, training volume was similar between the groups, indicating that training frequency (e.g., how often muscle groups were trained) provided a greater impact on stimulating maximal strength and hypertrophy adaptations in experience, resistance-trained men. This is supportive of Hoffman and colleagues (21) who demonstrated that a greater training volume per muscle group was important for stimulating strength gains in experienced, strength-trained athletes.

In the present investigation, maximal strength gains were optimized with higher training frequencies and TB workouts, while

**Table 4**

**Results of the muscle morphology assessments pre and post the 10-wk training program in the TB and SR groups.***

| Assessment | TP group | SR group | Group difference |
|---|---|---|---|
| VLMT (mm) | | | |
| Pre | 18.2 ± 3.7 | 16.6 ± 93.4 | $F$ = 5.185 |
| Post | 18.8 ± 3.7 | 18.3 ± 3.4 | $p$ = 0.037 |
| | | | $\eta^2$ = 0.245 |
| VLPA (mm) | | | |
| Pre | 12.4 ± 1.2 | 10.9 ± 11.2 | $F$ = 0.056 |
| Post | 11.7 ± 1.45 | 11.2 ± 1.9 | $p$ = 0.815 |
| | | | $\eta^2$ = 0.004 |
| PECMT (mm) | | | |
| Pre | 21.3 ± 3.4 | 19.8 ± 4.0 | $F$ = 0.006 |
| Post | 23.4 ± 4.5 | 22.0 ± 4.5 | $p$ = 0.939 |
| | | | $\eta^2$ = 0.001 |
| TRAPMT (mm) | | | |
| Pre | 12.1 ± 2.7 | 11.7 ± 1.5 | $F$ = 1.326 |
| Post | 13.2 ± 3.3 | 13.7 ± 1.9 | $p$ = 0.266 |
| | | | $\eta^2$ = 0.077 |

*TB = total body; SR = split routine; VLMT = vastus lateralis muscle thickness; VLPA = vastus lateralis pennation angle; PECMT = pectoralis major muscle thickness; TRAPMT = trapezius muscle thickness.



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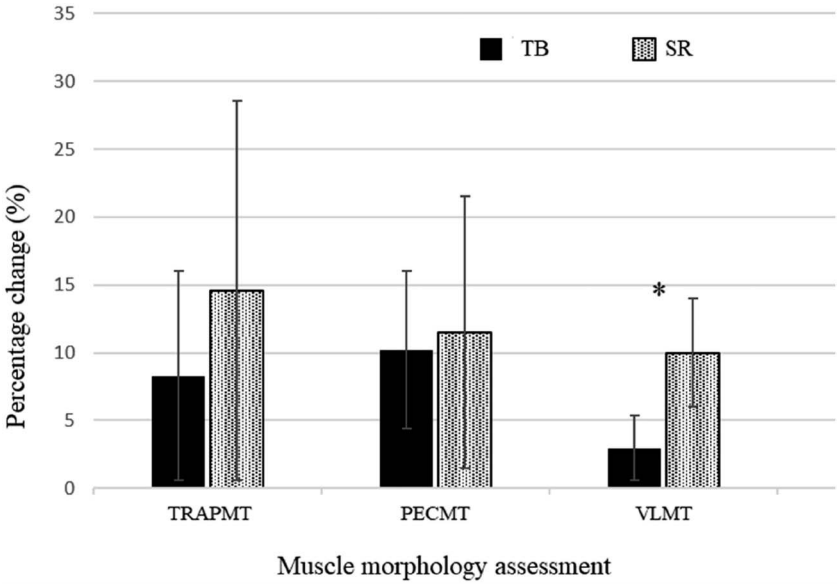


**Figure 3.** Percentage changes in muscle morphology from pre to post the 10-week training program in both the TB and SR groups. *Significant difference between the TB and SR groups. SR = split routine; TB = total body; TRAPMT = trapezius muscle thickness; PECMT = pectoralis major muscle thickness; VLMT = vastus lateralis muscle thickness.

muscle hypertrophy was optimally stimulated with lower training frequencies and an SR approach. TB routines are characterized by high training frequencies of different muscle groups and lower metabolic stress for each workout compared with SR. Greater gains in maximal strength, in the absence of significant differences in muscle hypertrophy, suggest that greater improvements in neural components occurred in TB compared with SR. According to McLester et al. (25), limited training volume per muscle group for each workout and high training frequencies may promote explosive intent for each repetition and encourage neural activation. Moreover, several low-volume exercises for the same muscle groups performed in subsequent days may paradoxically speed the recovery process, reducing muscle inflammation and swelling (3). Reductions in muscle inflammation and accelerations in the recovery rate may be appropriate to maximize neural adaptations and enhance training intensity. Higher training frequencies seem to be particularly appropriate to stimulate neural adaptations, when multijoint exercises are performed (29). High training frequencies may also be beneficial in optimizing exercise technique and motor coordination (26) through an optimal distribution of the training volume per muscle group. By contrast, SR workouts are characterized by concentrated training volumes per muscle group, producing high levels of intramuscular metabolic stress and muscle inflammation lasting for several days after the training session (14). Metabolic stress may stimulate hypertrophic effects on trained muscles by stimulating changes in hormone concentrations (15,16,24). Split routine training programs, however, ensure complete recovery between the training sessions focused on the same muscle groups (22). This workload distribution may be optimal to stimulate hypertrophic adaptations (32) but less effective for strength improvements. The present investigation also suggests that muscle hypertrophy and strength responses may not be aligned. This is consistent with Damas et al. (8) who reported a relative independence between neural adaptations and hypertrophic responses in young untrained men after an 8-week resistance training program.

A possible limitation of this study is that resistance training programs for competitive athletes usually last for several months, while in the present investigation, the training period was 10 weeks only. In addition, there are many types of SR training programs (e.g., 4-day split in which the workouts for days 1 and 3 are similar, and the workouts for days 2 and 4 are similar) and whether the results of this study would be consistent with a different program design is not known. Another possible limitation of this study is that 1RM tests may have been influenced by the isokinetic and isometric assessments performed 24 hours before.

## Practical Applications

This study demonstrated that both TB and SR 10-week training programs can significantly increase maximal strength and muscle mass gains in experienced, resistance-trained men. However, a TB approach may be optimal to stimulate maximal strength adaptations in highly trained men. The use of an SR training program, however, may be more conducive in stimulating muscle growth by concentrating the training volume for each muscle group in a single workout. Strength and conditioning coaches should be aware that different strategies may be adopted during different phases of a periodized strength training program to better stimulate either maximal strength or muscle hypertrophy development. In particular, SR may be more appropriate during a hypertrophy phase of a block periodization program, while TB approach may be suitable for the maximum strength phase.

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