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

This is the final peer-reviewed author's accepted manuscript (postprint) of the following publication:

Published Version:

Bartolomei, S., Nigro, F., Malagoli Lanzoni, I., Masina, F., Di Michele, R., Hoffman, J.R. (2021). A Comparison Between Total Body and Split Routine Resistance Training Programs in Trained Men. JOURNAL OF STRENGTH AND CONDITIONING RESEARCH, 35(6), 1520-1526 [10.1519/JSC.0000000000003573].

Availability:

This version is available at: <https://hdl.handle.net/11585/906365> since: 2025-02-17

Published:

DOI: <http://doi.org/10.1519/JSC.0000000000003573>

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A comparison between total body and split routine resistance training programs in resistance trained men.

Abstract

The purpose of the present investigation was to compare the effects of two resistance training programs; either total body (TB) or split routine (SR) workouts on maximal strength and muscle hypertrophy in trained men.

Twenty-one resistance trained men were randomly assigned to a total body (TB: age=24.1±4.4y; body weight=78.7±11.3kg; body height=177.0±3.9cm) or split routine group (SR: age=24.9±4.2y; body mass=79.2±9.5kg; body height=175.2±6.0cm). Both groups performed a 10-week resistance training program. Isokinetic bench press at 75 and 25 cm/sec (ISOK75 and ISOK25, respectively), isometric bench press (ISOBP), isometric squat (ISOSQ), and one repetition maximum (1RM) BP and SQ assessments were performed pre and post training. Muscle thickness of the pectoralis major (PECMT), trapezius (TRAPMT), and vastus lateralis (VLMT) muscles were also evaluated at the same timepoints.

Significant ($p<0.05$) improvements were observed in both groups for all strength assessments and muscle thicknesses. Only changes in ISOK25 were significantly ($p=0.025$) greater in TB than in SR, while significantly greater ($p=0.030$) changes in VLMT were detected in SR compared to TB.

Results indicate that a TB training paradigm may be more appropriate for maximal strength improvement strength, while a SR training protocol may be more optimal to stimulate muscle growth in experienced, resistance-trained men.

Keywords: strength, ultrasound, training load, force plates

Introduction

Training frequency is generally defined as the number of workouts performed within a week (Wernborn, Augustsson, & Thomeé, 2007). In resistance training however, training frequency may be also referred to the number of times a specific muscle group is trained per week (Schoenfeld, Ratamess, Peterson, Contreras, & Sonmez, 2015). This parameter is influenced by the number of resistance workouts per week and by the number of muscle groups stimulated during each training session. Total Body (TB) and Split Routine (SR) training paradigms represent two of the most common approaches to organizing resistance training workouts (Schoenfeld et al., 2015). TB sessions are characterized by all muscle groups being trained during each workout. In contrast, SR training programs focus on specific muscle groups (e.g., chest, shoulders and triceps), often use several resistance exercises for each specific muscle group and exercise each muscle group either once or twice a week (Fleck, & Kraemer, 2014). Both training paradigms are followed by strength and power athletes and sport enthusiasts; SR however, is more common than TB among advanced bodybuilders (Hackett, Johnson, & Chow, 2013), while TB is more popular among weightlifters (Everett, 2009; Fry et al., 2003). Previous research has also indicated that the use of a split routine training program may be beneficial for strength development by allowing a greater number of assistance exercises to be performed (Hoffman, Kraemer, & Fry, 1990). The increase in the number of assistance exercises appears to be an important stimulus for increasing strength in the experienced, trained strength/power athlete (Hoffman et al., 1990). However, some weightlifting and powerlifting coaches consider the TB approach a more appropriate training method for their athletes (Stone, Sands, & Stone, 2006; Colquhoun et al., 2018). The rationale behind TB training is that performing a few exercises for each muscle group in the workout, may allow athletes to maintain a greater training intensity. Many exercises focused on the same muscle group may reduce total training volume due to excessive fatigue. The SR approach

however, provides a considerable amount of time between the workouts focused on the same muscle group and several days are dedicated to muscle recovery (Kerksick et al., 2009).

Several studies have compared TB and SR strategies in different populations (Calder, Chilibeck, Webber, & Sale, 1994; Schoenfeld et al. 2014, 2015). Schoenfeld et al. (2014) did not report any significant difference in muscle hypertrophy adaptations between a powerlifting-style TB program and a bodybuilding-style SR program in resistance-trained men following 8-weeks of training. The TB group however, experienced greater improvements in maximal strength. Although both training programs were volume-equated, training schemes were different in regards to training intensity and recovery time between sets. In addition, muscle thickness of only the biceps brachii was measured to evaluate the individual hypertrophic response (Schoenfeld et al., 2014). More recently the same investigative team (Schoenfeld et al., 2015) reported superior gains in muscle hypertrophy following a TB scheme compared to SR. On the other hand, this latter study reported no significant differences between the two training paradigms for maximal strength adaptations. Both studies used trained men as participants, with a strength training experience of 4.2 and 4.5 y, respectively. Both TB and SR training programs however, included a total of 18 sets of 8-12 repetitions in each of the three training sessions provided per week (Schoenfeld et al., 2015). However, bodybuilders and strength athletes usually perform a considerably greater number of sets in each workout and more training sessions per week (Amirthalingam et al., 2017) resulting in elevated training volume. A study by Calder et al. (1994), reported similar results between a whole body and a SR resistance training program during a 5-month training period in untrained women. Both gender and training experience may influence the adaptations to the different resistance training paradigms and training frequencies (Grgic et al., 2018).

Most scientific studies have been performed using untrained individuals as participants with very low training frequencies per week (Ochi et al., 2018, Candow, & Burke, 2007). The

limitations of these studies make it difficult to draw conclusions about the superiority of either TB or SR approach in resistance-trained men. Thus, the aim of the present investigation was to compare the effects of a 10-week TB resistance training program to a SR program of the same length, on maximal strength and muscle hypertrophy in resistance-trained men. It was hypothesized that TB may elicit greater gains on maximal strength while SR may result in greater hypertrophic responses over the course of the training period.

Method

Participants

Twenty-one experienced resistance trained men were randomly assigned to either a total body group (TB group: $n = 10$;age = 24.1 ± 4.4 y; body weight = 78.7 ± 11.3 kg; body height = 177.0 ± 3.9 cm; body fat = 10.4 ± 1.8 %) or a split routine training group (SR group: $n = 11$; age = 24.9 ± 4.2 y; body weight = 79.2 ± 9.5 kg; body height = 175.2 ± 6.0 cm; body fat = 12.3 ± 3.5 %). Participants participated in resistance-training at least three times per week for more than three years (mean $\pm$ SD = 6.6 ± 3.5 y of experience) and were familiar with both powerlifting and weightlifting exercises. Participants were not permitted to use any dietary supplementation and did not consume any androgens or other performance enhancing drugs. Screening for performance enhancing drug use and additional supplementation was accomplished via a health questionnaire completed at the recruitment stage. All participants signed an informed consent document after being informed about the risks and benefits of the study. Exclusion criteria included injuries occurred in the year prior to the study. Participants were asked to abstain from alcohol, caffeine and resistance training for at least 24 h prior to all assessments. The study was approved by the University's Institutional Review Board. bioethics committee.

Experimental Design

Participants were randomly assigned to a TB or to a SR training group. Both groups performed a 10-week training program using the same exercises and the same total number of repetitions. The first group (TB) performed a 10-week training program including resistance training sessions involving several muscle groups of both upper and lower body, while the second group (SR) performed a training program involving a limited number of muscle groups in each workout. Participants were assessed for upper- and lower-body maximal strength before and after the training program. Measurements of muscle architecture and body composition were also collected at the beginning and at the end of the training period.

Testing Procedures

Anthropometric evaluations were performed before the first assessment session. Body measurements included body mass, height and body fat composition. Body mass was measured to the nearest 0.1 kg using a scale (Seca 769, Seca Scale Corp., Munich, Germany). Body fat percentage was estimated from skinfold caliper measures using the method of Evans et al. (2005). The same investigator performed all skinfold analysis assessments. Prior to the strength and power assessments, participants performed a standardized warm-up consisting of five min 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.

Isokinetic bench press strength measurements were performed using a linear isokinetic dynamometer (Lido Loredan Linea, Shirley, NY). Participants were positioned with their elbows at 90° of flexion on a bench and their grip width was measured and recorded. Isokinetic concentric measurements were performed at a velocity of 75 cm/s (ISOK75) and 25 cm/s

(ISOK25). 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 was performed using a power rack that permitted fixation of the bar. The bench was positioned over a force plate (Kistler 9260, 500 Hz, Winterthur, Switzerland). Participants were required to position themselves on the bench with a 90° elbows flexion and they were not permitted to position the feet on the ground. Elbow angle, and grip width were measured to reproduce the same position for all testing sessions. Participants were asked to press against the bar as hard as possible for 6 s. The force expressed against the bar was transmitted by the bench to the force plate and the 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. Participants were required to perform two maximal 6-s isometric contractions in both ISOBP and ISOSQ and a 3-min recovery time between each attempt was observed. For both IBP and ISQ, peak force was measured. Intraclass coefficients were 0.85 (SEM = 267.1 N) and 0.83 (SEM = 219.6 N) for ISOBP and ISOSQ, respectively. Participants reported back to the laboratory the next day and performed one-repetition maximum (1RM) test in the parallel squat (SQ) and bench press (BP) exercises using the method previously described by Hoffman (2014). The same warm-up previously described was performed by the participants before the 1RM test. During the 1RMSQ participants were asked to reach a position where the greater trochanter of the femur was at the same level of the knee. In the 1RMBP, participants were required to lower the bar to their chest before initiating the concentric movement. A 3-minute recovery time was observed between 1RM attempts. During all strength measurements, participants were verbally encouraged by the study investigators.

Ultrasonography measurements

Non-invasive skeletal muscle ultrasound images were collected from the participant's right side of the body. Prior to 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 (Bartolomei et al., 2017). VL muscle thickness (VLMT) and pennation angle (VLPA) required the participant 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. PEC muscle thickness (PECMT) was measured at the site between third and fourth costa under the clavicle midpoint (Yasuda, Fujita, Ogasawara, Sato, & Abe, 2010). TRAP muscle thickness (TRAPMT) was measured at the midpoint of the muscle belly at T1 level, where the muscle borders were parallel (O'Sullivan, Meaney, Boyle, Gormley, & Stokes, 2017). The same investigator performed all landmark measurements for each participant.

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 = 50dB; 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. Intra-class correlation coefficients (ICCs) were 0.96 (SEM = 0.63 mm); 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 TB and SR groups can be seen in Table 1 and Table 2, respectively. All participants 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 while 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-min rest time between sets. Intensity was selected as the load allowing the subject to perform 6 repetitions without reaching volitional failure, with one repetition in reserve (1-RIR; Zourdos et al., 2016).

Participants were encouraged to increase the resistance used per workout if they were able to perform the required number of repetitions. Participants recorded all workouts in a logbook, which was collected by one of the investigators after each workout. The total training volume (TTV) was calculated for each participant based on the total load lifted in each workout and each week. To avoid the potential ergogenic effect of music (Bartolomei, Di Michele, & Merni, 2015), participants were not allowed to listen to music during either the resistance training or testing sessions.

(Place Table 1 and Table 2 here)

Statistics

A Shapiro-Wilk test was used to test the normal distribution of the data. Performance, morphological data and training volume in the first and in the tenth week of the training program, were analyzed by a two-way (group [TB vs. SR] x time [PRE vs. POST]) mixed-factorial analysis of variance (ANOVA). In addition, TTV performed by each group during the

10-week programs was compared using a dependent t test. An alpha level of $p < 0.05$ was used to determine statistical significance. In a separate analysis, mean percentage change values ($[(\text{POST mean} \times \text{PRE mean})/(\text{PRE mean}) \times 100]$) was evaluated with 95% confidence intervals. All data are reported as mean $\pm$ SD. For effect size (ES), the partial eta squared statistic was reported, and according to Green, Salkind and Jones (1996), 0.01, 0.06, and 0.14 represent small, medium, and large ESs, respectively.

Results

Performance assessments

TTV for both TB and SR groups are depicted in Figure 1. Although no significant group $\times$ time interactions were detected for the total load lifted between the first and tenth week of the training program ($F = 0.540$; $p = 0.473$; $\eta^2 = 0.031$), a significant effect for time was observed in the total load lifted between the first and the tenth week of training ($F = 75.133$; $p < 0.001$; $\eta^2 = 0.815$). No significant differences were noted between TB and SR on TTV ($F = 0.009$; $p = 0.767$; average = 143480 ± 33713 kg and 147762 ± 28194 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. A significant group $\times$ time interaction ($F = 6.042$; $p = 0.025$; $\eta^2 = 0.262$) and a significant main effect for time ($F = 13.095$; $p = 0.002$; $\eta^2 = 0.435$) were found 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 interaction nor main effect for time was noted between TB and SR for ISOK75 ($F = 2.218$; $p = 0.751$; $\eta^2 = 0.006$), ISOBP ($F = 0.308$; $p = 0.586$; $\eta^2 = 0.018$) and ISOSQ ($F = 0.460$; $p = 0.507$; $\eta^2 = 0.026$). In addition, no significant interactions were observed for either 1RMSQ and 1RMBP ($F = 1.185$; $p = 0.295$; $\eta^2 = 0.078$ and $F = 0.067$; $p = 0.799$; $\eta^2 = 0.005$, respectively).

However, significant main effects for time were noted for ISOK75 ($F = 5.743$; $p = 0.028$; $\eta^2 = 0.253$), ISOBP ($F = 10.289$; $p = 0.005$; $\eta^2 = 0.377$), ISOSQ ($F = 17.121$; $p = 0.001$; $\eta^2 = 0.502$), 1RMSQ ($F = 89.003$; $p < 0.001$; $\eta^2 = 0.864$) and 1RMBP ($F = 49.718$; $p < 0.001$; $\eta^2 = 0.780$).

(Place Figure 1, Figure 2 and Table 3 here)

Muscle morphology assessments

Results of the muscle morphology assessments and percent changes in muscle architecture are reported in Table 4 and Figure 3, respectively. A significant group x time interaction was noted for VLMT ($F = 5.572$; $p = 0.030$; $\eta^2 = 0.247$). Increases in muscle size for VLMT was significant greater for SR compared to TB. Significant effects over time were noted for both PECMT ($F = 36.881$; $p < 0.001$; $\eta^2 = 0.685$) and TRAPMT ($F = 24.243$; $p < 0.001$; $\eta^2 = 0.589$). However, no significant interactions were noted for PECMT ($F = 0.005$; $p = 0.947$; $\eta^2 = 0.005$) or TRAPMT ($F = 1.713$; $p = 0.208$; $\eta^2 = 0.092$). No significant group interactions ($F = 1.318$; $p = 0.267$; $\eta^2 = 0.072$) and no main effects of time ($F = 0.300$; $p = 0.591$; $\eta^2 = 0.017$) were detected for VLPA.

(Place Table 4 and Figure 3 here)

Conclusion

The present study investigated the effects of two 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 two groups during the 10-week study in both groups, indicating that the two 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 ISB, ISQ, ISOK75 bench press, 1RMBP and 1RMSQ for both groups, with no group differences noted. The only between-group difference was observed in isokinetic strength expressed at $25 \text{ cm} \cdot \text{s}^{-1}$, in which significantly greater increases were noted for TB compared to SR for (ISOK25; +12.9 % and +2.3 % in TB and SR, respectively). Superior increases in this parameter in TB may be related to a more frequent stimulation of pectoral and triceps muscles compared to SR.

In the present study, the SR program appeared 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 to TB (+8.3%). The results of this study do not support the recent study by Schoenfeld and colleagues (2015) who reported greater muscle hypertrophy from total body 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 (Grgic et al., 2018; Schoenfeld, Ogborn, & Krieger, 2016). Training volume, and not training frequency, has been reported to be the most important factor contributing to increases in muscular strength, (Ralston, Kilgore, Wyatt, & Baker, 2017). However, the present investigation showed a significant impact in training frequency of muscle groups on stimulating maximal strength and hypertrophy adaptations in resistance trained men, even when training volume was not significantly different between the groups. This is supportive of previous work of Hoffman and colleagues (1990) that demonstrated that greater training volume (e.g, more exercise 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 muscle hypertrophy was optimally stimulated with lower training frequencies and a SR approach. TB routines are characterized by high training frequencies of different muscle groups and lower metabolic stress for each workout compared

to SR. Greater gains in maximal strength, in absence of significant differences in muscle hypertrophy, suggest that greater improvements in neural components occurred in TB compared to SR. According to McLester, Bishop and Guilliams (2000), limited training volume per muscle group for each workout and high training frequencies, may promote explosive intent in 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 (Bartolomei et al., 2019). Reductions in muscle inflammation and accelerations in the recovery rate may be appropriate to maximize neural adaptations and to influence training intensity. Higher training frequencies appear to be particularly appropriate to stimulate neural adaptations, when multi-joint exercises are performed (Rhea, Alvar, Burkett, & Ball, 2003). High training frequencies may also be beneficial in optimizing exercise technique and motor coordination (Ochi et al., 2018) through an optimal distribution of the training volume per muscle group. In 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 following the training session (Gonzalez et al., 2015). Metabolic stress may stimulate hypertrophic effects on trained muscles by stimulating changes in hormone concentrations (Goto, Ishii, Kizuka, & Takamatsu, 2005; Gotshalk et al., 1997; Mangine et al., 2017). SR training programs however, ensure complete recovery between the training sessions focused on the same muscle groups (Kerksick et al., 2009). This workload distribution may be optimal to stimulate hypertrophic adaptations (Schoenfeld et al., 2015) 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. (2019) who reported a relative independence between neural adaptations and hypertrophic responses in young untrained men following an 8-week resistance training program. A possible limitation of the present study is that resistance training

programs for competitive athletes usually last for several months, while in the present investigation the training period lasts for 10 weeks only. In addition, there are many types of split routine training programs (e.g., four-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.

What does this article add?

To the best of our knowledge, this is the first study to compare TB and SR programs characterized by the same number of training session per week but different training frequencies of each muscle group and using typical training approaches followed by strength and power athletes. The present study has shown that both TB and SR 10-week training programs can result in significant maximal strength and muscle mass gains in resistance trained men. However, a TB approach may be optimal to stimulate maximal strength adaptations in highly trained men. However, the use of a SR training program may be more conducive in stimulating muscle growth by concentrating the training volume for each muscle group on a single workout.

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Figure Captions

Figure 1. Training volume for both TB and SR groups during the training period.

Figure 2. Percentage changes in strength assessments from pre to post the 10-week training program in both TB and SR groups. 1RMBP = bench press 1RM; 1RMSQ = squat 1RM; ISOK75 = isokinetic force at 75 cm/s; ISOK25 = isokinetic force at 25 cm/s; ISOBP = isometric bench press; ISOSQ = isometric squat. # indicates a significant main effect of time. * indicates a significant interaction between TB and SR groups.

Figure 3. Percentage changes in muscle morphology from pre to post the 10-week training program in both TB and SR groups. TRAPMT = trapezius muscle thickness; PECMT = pectoralis major muscle thickness; VLMT = vastus lateralis muscle thickness. # indicates a significant main effect of time. * indicates a significant interaction between TB and SR groups.