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Original Research

Order of Resistance Training Cycles to Develop Strength and Muscle Thickness in Resistance-Trained Men: A Pilot Study

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ABSTRACT

International Journal of Exercise Science 14(4): 644-656, 2021. The aim of the present study was to assess the chronic effects of different order of resistance training cycles on strength and muscle thickness of recreationally resistance-trained men. The study sample was composed of 16 healthy men (age: 25.0 ± 3.8 years, height: 1.77 ± 7.6 cm, total body mass: 81.7 ± 10.4 kg, RT experience: 4.6 ± 0.7 years, relative bench press one repetition maximum: 1.2 ± 0.1, relative squat one-repetition maximum: 1.5 ± 0.2). According to baseline maximal strength, participants were allocated in one of the following groups: Maximal Strength-Strength Endurance (MS-SE) (six weeks of a maximal strength cycle followed by six weeks of a strength endurance cycle); Strength Endurance –Maximal Strength (MS-SE) (six weeks of a strength endurance cycle followed by six weeks of a maximal strength cycle). The following measurements were performed in the pre and post intervention periods: one-repetition maximum (1RM) on parallel back squat and bench press exercises, muscle thickness evaluation of biceps brachialis (MT_{BB}), triceps brachialis (MT_{TB}), and vastus lateralis (MT_{VL}) by ultrasonography. Total load lifted (TLL) and Internal training load (ITL) were also assessed. Both groups presented significant increases in bench press (MS-SE $p = 0.001$, SE-MS $p = 0.003$) and half squat (MS-SE $p = 0.004$, SE-MS $p = 0.001$) 1RM, MT_{BB} (MS-SE $p = 0.020$, SE-MS $p = 0.005$) and MT_{TB} (MS-SE $p = 0.001$, SE-MS $p = 0.001$). For MT_{VL}, a significant increase was observed only for MS-SE group (MS-SE $p = 0.032$, SE-MS $p = 0.143$). No significant difference between groups was observed for any strength or morphological outcomes. In conclusion, both MS-SE and SE-MS training cycles are effective strategies to enhance resistance training adaptations in trained men.

KEY WORDS: Periodization, loading zones, repetition range, volume

INTRODUCTION

The benefits of a resistance training (RT) program have been substantially reported by the scientific literature, especially regarding muscle strength and hypertrophy-related outcomes (2). Usually, the primary strength increment induced by RT is explained by neural and, lately, morphological adaptations (10). In order to maximize these outcomes, proper prescription and periodization of RT variables and loads are required (2, 13). A traditional distribution of RT programs usually develops a strength endurance foundation in the initial phase of the program, whereas other physical capacities (maximal strength and power) are emphasized later into a training cycle (10).

Distinct manipulations of RT variables with same total load lifted (TLL) have been shown to elicit a similar increment in strength and muscle hypertrophy (3, 5, 19, 31). Additionally, protocols consisting of higher (80% 1RM) vs. moderate intensity (60% 1RM) seem to induce a similar hypertrophic adaptation within volume-equated conditions (19). On the other hand, for dynamic maximal strength development, different loading strategies result in a larger increases for low vs. moderate repetitions scheme (e.g., 7 x 3RM vs. 3X10RM and/or 4x3-5RM vs. 3x9-11RM) (7, 27), even in a non-equalized volume conditions (3x2 at 4RM vs. 3x8-12RM) (28).

Although the magnitude of morphological and strength responses resulting from different RT schemes is well documented, the temporal distribution of training cycles is still understudied. Loturco et al. (20), for instance, described similar improvements in back squat one-repetition maximum test (1RM) following three different cycle organizations of strength and power training loads (heavy resistance exercise, jump squat, countermovement jump). A similar strength increment in the bench press and leg extension exercises was also reported by Prestes et al. (25) following distinct periodization programs (linear vs. reverse linear). Total training volume between protocols was matched in both experiments.

In addition, due to the relevant role of mechanical tension for promoting muscle hypertrophy, one can assume that performing a strength-oriented program prior to a hypertrophy-oriented one could lead practitioners to support the use of heavier loads during the latter phase, with consequent increased levels of mechanical stress experienced by muscle fibers (10, 13). However, to the best of the authors' knowledge, the chronic effects regarding the order of training cycles in muscle morphology have not been investigated yet. Therefore, the aim of the present study was to verify if different orders of RT cycles with equated volume affect maximum strength, muscle thickness, and training load (external and internal) in recreationally resistance-trained men. The initial hypothesis was that the equalization of the total work performed would be more important than the cycle temporal sequence for strength and morphological improvements.

METHODS

Participants

Twenty-two recreationally resistance-trained men (age: 25.0 ± 3.8 years (range 18-34), height: 1.77 ± 7.6 cm, total body mass: 81.7 ± 10.4 kg, RT experience: 4.6 ± 0.7 (range 1-10 years), relative bench press one repetition maximum ($1RM_r$): 1.2 ± 0.1, relative squat one-repetition maximum ($1RM_r$): 1.5 ± 0.2) volunteered to participate in this study. The sample size was justified by a priori power analysis based on a pilot study, where the vastus lateralis MT was assessed as the outcome measure with a target effect size (ES) difference of 0.75, an alpha level of 0.05, and a power ($1-\beta$) of 0.80 (12). All participants reported performing RT a minimum of three days per week for at least one year and regularly performed (minimum frequency of once a week) all exercises included in the training intervention and strength tests for at least one year prior to entering the study. Moreover, participants were free from any existing musculoskeletal disorders, no history of injury with residual symptoms in the trunk, upper, and lower limbs within the last year, and stated they had not taken anabolic steroids and/or any ergogenic supplement for a minimum period of twelve months. From 22 participants that initiated experimental protocol, four from MS-SE group and two from SE-MS group were excluded of analysis due to injury not related to experiment and/or voluntary quitting. Therefore, MS-SE and SE-MS groups had seven and nine participants, respectively. All procedures were in accordance with the Declaration of Helsinki and were carried out fully in accordance to the ethical standards of the International Journal of Exercise Science (22). Institutional Review Board at Methodist University of Piracicaba (Sao Paulo) approved the protocol (1.749.1411). All subjects read and signed an informed consent document.

Table 1. Baseline descriptive statistics (mean ± SD).

Variables	MS-SE (n=7)	SE-MS (n=9)	*P value*
Age (years)	27.1 ± 4.9	23.7 ± 2.5	0.128
Total Body Mass (kg)	85.9 ± 7.6	78.1 ±11.2	0.186
Height (cm)	180 ± 7	174 ± 7	0.429
$1RM_{BENCH}$(kg)	89 ± 32	82 ± 29	0.905
$1RM_{SQUAT}$ (kg)	138 ± 33	126 ± 15	0.988
RT Experience (years)	5.0 ± 2.8	4.4 ± 2.5	0.117
RT Frequency (sessions $\cdot wk^{-1}$)	4.8 ± 0.7	4.7 ± 0.9	0.689
RT Lower Body Frequency (sessions $\cdot wk^{-1}$)	1.4 ± 0.5	1.4 ± 0.5	0.925
RT Upper Body (sessions $\cdot wk^{-1}$)	1.6 ± 0.5	1.7 ± 0.5	0.886

MS-SE = Maximal strength – Strength endurance training group; SE-MS = Strength endurance – Maximal strength training group; $1RM_{BENCH}$ = one maximal repetition test in the bench press exercise; $1RM_{SQUAT}$= one maximal repetition test in the squat exercise; RT = resistance training; sessions $\cdot wk^{-1}$ = sessions per week.

Protocol

The present study followed a randomized, longitudinal design (24). Participants were pair-matched according to baseline maximal strength and then randomly assigned to one of two experimental groups: the first group was Maximal Strength-Strength Endurance (MS-SE) (n = 7), which participants performed six weeks of maximal strength training followed by six weeks of strength endurance training, and the second group was Strength Endurance-Maximal strength (SE-MS) (n = 9), which the participants performed the inverse order of the 1st group´s training scheme. The experimental period lasted 15 weeks: 1st week – familiarization period and pre-intervention measures (baseline), 2nd - 7th week – first training intervention period, 8th week – middle measures period, 9th - 14th – second training intervention period, and 15th – final measures. Testing was carried out pre, middle, and post-intervention periods for maximal voluntary muscle strength (1RM test for bench press and parallel back squat exercises) and muscle thickness (MT) of the biceps brachii, triceps brachii, and vastus lateralis. Internal and external training loads were also collected during the intervention period. Additionally, participants were trained and instructed to record their dietary intake.

Participants were instructed to refrain from performing any additional RT during the intervention period. Both training protocols are represented in Tables 2 and 3. Maximal strength training cycle consisted in three exercises, six sets per muscle group at 2-4RM, with three-minute rest intervals between. Strength-endurance training cycle consisted in four exercises, eight sets per muscle group at 10-12RM, with one-minute rest intervals between sets. Both training cycles were performed four times per week (Mondays/Tuesday/Thursday/Friday) and each muscle group was trained twice each week. Participants were instructed to perform each set to the point of momentary concentric muscular failure, operationally defined as the inability to perform another concentric repetition while maintaining adequate form. During the familiarization sessions, subjects were instructed on how to adopt a controlled cadence of approximately one repetition/three seconds. However, for both the strength endurance and maximal strength protocols, if the cadence could not be maintained with the progression of the set towards the concentric failure, the set should be interrupted. All participants reported a rating of perceived exertion (RPE) based on the RPE/Repetitions in Reserve scale of 9.5 - 10 for all sets and exercises in RT sessions (16). This instrument was adopted in order to ensure that all participants performed the training sets to muscular failure, equating the experienced effort for both experimental groups. All routines were directly supervised by the research assistants to ensure the correct performance of the respective routines. Training loads were adjusted after each set. If the upper limit of repetition range was achieved (> 4RM and > 10 RM for maximal strength and hypertrophy, respectively) increments of 5-10% of load were implemented.

Table 2. Maximal Strength Protocol adopted during the intervention period.

Days of Week	Exercise	Sets/Reps
Monday/Thursday	Barbell bench press	3 X 2-4RM
Monday/Thursday	Inclined bench press	3 X 2-4RM
Monday/Thursday	Barbell squat	6 X 2-4RM
Tuesday/Friday	Pronated barbell row	3 X 2-4RM
Tuesday/Friday	Supinated barbell row	3 X 2-4RM
Tuesday/Friday	Barbell stiff deadlift	6 X 2-4RM

Rest intervals of three minutes.

Table 3. Strength Endurance Protocol adopted during intervention period.

Days of Week	Exercise	Sets/Reps
Monday/Thursday	Barbell bench press	4 X 10-12RM
Monday/Thursday	Dumbbell fly	4 X 10-12RM
Monday/Thursday	Lying elbow extension	4 X 10-12RM
Monday/Thursday	Barbell squat	8 X 10-12RM
Tuesday/Friday	Pronated barbell row	4 X 10-12RM
Tuesday/Friday	Inverted dumbbell fly	4 X 10-12RM
Tuesday/Friday	Biceps curl	4 X 10-12RM
Tuesday/Friday	Barbell stiff deadlift	8 X 10-12RM

Rest interval of one minute.

To avoid potential dietary confounding of results, participants were advised to maintain their customary nutritional regimen and to avoid taking any supplements during the study period. Dietary nutrient intake was assessed by 24-hour food recalls on two nonconsecutive weekdays and one day of the weekend. The estimation of energy intake (macronutrients) was analyzed by NutWin software (UNIFESP, São Paulo, Brazil). The estimated food intake was assessed during weeks one (baseline), eight, and fifteen (post-intervention period) of the experimental period.

Upper and lower-body maximum strength was assessed by 1RM testing in the bench press ($1RM_{BENCH}$) and parallel back squat ($1RM_{SQUAT}$) exercises. Participants 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 the conclusion of the study. Maximum strength testing was consistent with recognized guidelines as established by the National Strength and Conditioning Association (NSCA) (15). The test-retest intraclass correlation coefficient (ICC), the coefficient of variation (CV), and the standard error of the measurement (SEM) were calculated through the data collected during the familiarization period and the pre-intervention period (five days between the test-retest). The ICC, CV, and SEM for $1RM_{BENCH}$ were 0.989, 0.8%, and 2.05 kg, respectively. The ICC, CV, and SEM for $1RM_{SQUAT}$ were 0.990, 0.7%, and 1.95, respectively.

Ultrasound imaging was used to obtain measurements of MT. A trained technician performed all testing using an A-mode ultrasound imaging unit (Bodymetrix Pro System; Intelametrix Inc., Livermore, CA, USA). Following a generous application of a water-soluble transmission gel (Mercur S.A. – Body Care, Santa Cruz do Sul, RS, Brazil) to the measured site, a 2.5-MHz linear probe was placed perpendicular to the tissue interface without depressing the skin. Equipment settings were optimized for image quality according to the manufacturer's user manual and held constant among testing sessions. When the quality of the image was deemed to be satisfactory, the image was saved to the hard drive, and MT dimensions were obtained by measuring the distance from the subcutaneous adipose tissue–muscle interface to the muscle-bone interface per methods used by Abe et al. (1). Measurements were taken on the right side of the body at three sites: biceps brachii (MT_{BB}), triceps brachii (MT_{TB}), and vastus lateralis (MT_{VL}). Upper arm measurements were conducted while participants were standing and the measurements of the thigh muscle involved participants laying supine on an examination table.

For the anterior and posterior upper arm, measurements were taken 60% distal (lower part) between the lateral epicondyle of the humerus and the acromion process of the scapula. For the thigh muscles, measurements were taken 50% of the distance between the lateral condyle of the femur and greater trochanter. For each measurement, the examined limb was secured so as to minimize unwanted movement. To maintain consistency between pre- and post-intervention testing, each site was marked with henna ink (reinforced every week). In an effort to help ensure that swelling in the muscles from training did not obscure results, images were obtained 72 hours before commencement of the study and after the final training session. This is consistent with research showing that an acute increase in MT returns to baseline within 48 hours following a RT session (23). To further ensure accuracy of measurements, at least three images were obtained for each site. If measurements were within 1mm of one another the figures were averaged to obtain a final value. If measurements were more than 1mm of one another, a fourth image was obtained, and the closest 3 measurements were then averaged. All images were performed by the experienced researcher who was blind to the RT protocol performed.

The test-retest ICC for MT_{TB}, $MT_{BB,}$ and MT_{VL} was 0.998, 0.996, and 0.999, respectively. The CV for these measures was 0.6, 0.4, and 0.6%, respectively. The SEM for these measures was 0.42, 0.29, and 0.41 mm, respectively. Total load lifted (sets x repetitions x external load) was calculated from training logs filled out by research assistants for every RT session. The accumulated TLL (ATLL) was the sum of all RT weeks. Only repetitions performed through a full range of motion were included for analysis. The data were expressed in kilogram-force units (kgf). Participants reported their session RPE (sRPE), according to the OMNI-Resistance Exercise Scale (OMNI-RES) (validated to measure RPE in RT) (26). Participants were shown the scale 10 minutes after each session and asked: "How intense was your session?" and were requested to make certain that their RPE referred to the intensity of the whole session rather than the most recent exercise intensity (8). The internal training load (ITL) for each session was calculated multiplying the total time under tension spent in the session in minutes by the sRPE (14). Total ITL (ITL_{TOTAL}) was the sum of all RT weeks. The data were expressed in arbitrary units (AU).

Statistical Analysis
The normality and homogeneity of the variances were verified using the Shapiro-Wilk and Levene tests, respectively. Prior to analysis, all data were log-transformed for analysis to reduce bias arising from non-uniformity error (heteroscedasticity). The mean, standard deviation (SD), and 95% confidence intervals (CI) were used after data normality was verified. To compare mean values of the descriptive variables, TLL and ITL between-groups (MS-SE vs. SE-MS), a paired t-test was used. A repeated measures analysis of variance (ANOVA) was used to compare $1RM_{BENCH}$ and $1RM_{SQUAT}$ time effect (pre vs. post week six vs. post week twelve) x two groups (MS-SE vs. SE-MS). A repeated measures ANOVA 3 x 2 was used to compare time effect in MT_{BB}, MT_{TB}, MT_{VL} (pre-test, post week six, and post week twelve) and two groups. Post hoc comparisons were performed with the Bonferroni correction. Assumptions of sphericity were evaluated using Mauchly's test. Where sphericity was violated ($p < 0.05$), the Greenhouse–Geisser correction factor was applied. In addition, effect sizes were evaluated using a partial eta squared (η^2_p); with < 0.06, 0.06 - 0.14, and > 0.14 indicating a small, medium, and large effect, respectively. Effect sizes in absolute differences (pre vs. post protocol) in raw values of the variables using the standardized difference based on Cohen's d units by means (*d*) (9). The *d* results were qualitatively interpreted using the following thresholds: < 0.2: trivial, 0.2 - 0.6: small, 0.6 -1.2: moderate, 1.2 - 2.0: large, 2.0 - 4.0: very large, and > 4.0: extremely large (17). Trivial area $d < 0.2$ (gray bar) was used in Forrest Plot Graph. All analyses were conducted in SPSS-22.0 software (IBM Corp., Armonk, NY, USA). The adopted significance was $p \leq 0.05$. In addition, smallest worthwhile change (SWC) in dependent-variables was calculated by the formula SWC = typical error of the measurement (TEM) x 2 (17). We defined an individual as "responding" to training one with a response greater than 1SWC from zero for increases in muscle thickness; if not, he was considered as non-responder. The participants were classified as small/moderate responsiveness (1 to 6 SWC) and large responsiveness (> 6 SWC) (6). Data analysis was performed using a modified statistical Excel spreadsheet (17).

RESULTS

No significant difference was noted between groups in any baseline measurements ($p > 0.05$) (Table 1). There was no significant difference in any dietary intake variables (kcal, proteins, carbohydrate, and lipids grams) either within- or between-groups over the course of the study ($p > 0.05$).

Maximal dynamic strength: A significant main effect of time ($F_{2,12} = 46.664$, $p = 0.001$, $\eta^2_p = 0.886$), but not group x time interaction ($F_{1,12} = 0.652$, $p = 0.538$, $\eta^2_p = 0.098$), was observed for $1RM_{BENCH}$. There was a significant main effect of time ($F_{2,12} = 90.150$, $p = 0.001$, $\eta^2_p = 0.938$), but not group x time interaction ($F_{2,12} = 2.815$, $p = 0.099$, $\eta^2_p = 0.319$) for $1RM_{SQUAT}$ (Table 4).

Muscle Thickness: A significant main effect of time ($F_{1.108,6.647} = 18.699$, $p = 0.003$, $\eta^2_p = 0.757$), but not group x time interaction ($F_{2,12} = 1.857$, $p = 0.198$, $\eta^2_p = 0.236$) was observed for MT_{BB} (Table 4). The individual analyses showed that two participants from each group presented large responsiveness for MS-SE and SE-MS, (28%) and (22%), respectively (Figure 1). A significant main effect of time ($F_{2,12} = 18.377$, $p = 0.001$, $\eta^2_p = 0.754$), but not group x time interaction ($F_{2,12} = 0.420$, $p = 0.666$, $\eta^2_p = 0.065$) was observed for MT_{TB} (Table 4). The individual analyses showed that one participant from the MS-SE group (14%) and three participants from the SE-MS group (33%) presented large responsiveness (Figure 1). A significant main effect of time ($F_{2,12} = 11.121$, $p = 0.002$, $\eta^2_p = 0.650$) but not group x time interaction ($F_{2,12} = 2.020$, $p = 0.175$, $\eta^2_p = 0.252$) was observed for MT_{VL} (Table 4). The individual analyses showed that one participant from the SE-MS group (11%) presented large responsiveness, but none from the MS-SE group did (Figure 1).

Table 4. Pre, post six weeks, and post twelve weeks- muscle strength and morphology measures (mean ±SD).

Variables	Pretest	Post six-weeks	Post Twelve-weeks	Δ% pre vs. post six-weeks	Δ% pre vs. post twelve-weeks	time *P* value	time*group *P* value
$1RM_{BENCH}$ (kg)							
MS-SE	105 ± 11	119 ± 6*	125 ± 8*#	13.3	19.0	0.001	0.538
SE-MS	95 ± 12	105 ± 11	114 ± 10*#	10.5	20.0	0.003	
$1RM_{SQUAT}$ (kg)							
MS-SE	147 ± 31	176 ± 21*	189 ± 24*	19.7	28.6	0.004	0.099
SE-MS	126 ± 15	156 ± 19*	183 ± 26*#	23.8	45.2	0.001	
MT_{BB} (mm)							
MS-SE	40.7 ± 7.0	41.7 ± 6.4	43.2 ± 5.6*#	2.5	6.1	0.020	0.198
SE-MS	36.6 ± 4.8	38.9 ± 4.6*	39.6 ± 4.4*	6.3	8.2	0.005	
MT_{TB} (mm)							
MS-SE	33.6 ± 4.1	34.9 ± 3.1	37.4 ± 2.8*	3.9	11.3	0.001	0.666
SE-MS	28.7 ± 3.3	31.4 ± 5.0*	33.2 ± 5.4*#	9.4	15.2	0.001	
MT_{VL} (mm)							
MS-SE	46.8 ± 6.5	47.1 ± 7.1	48.5 ± 7.0*	0.6	3.6	0.032	0.175
SE-MS	38.1 ± 8.2	40.2 ± 9.2	40.8 ± 9.0	5.5	7.1	0.143	

MT_{BB} = muscle thickness of the biceps brachii muscle, MT_{TB} = muscle thickness of the triceps brachii muscle, MT_{VL} = muscle thickness of the vastus lateralis muscle. *Significantly greater than the corresponding pre-intervention value ($p < 0.05$). #Significantly greater than the corresponding post six weeks value ($p < 0.05$).

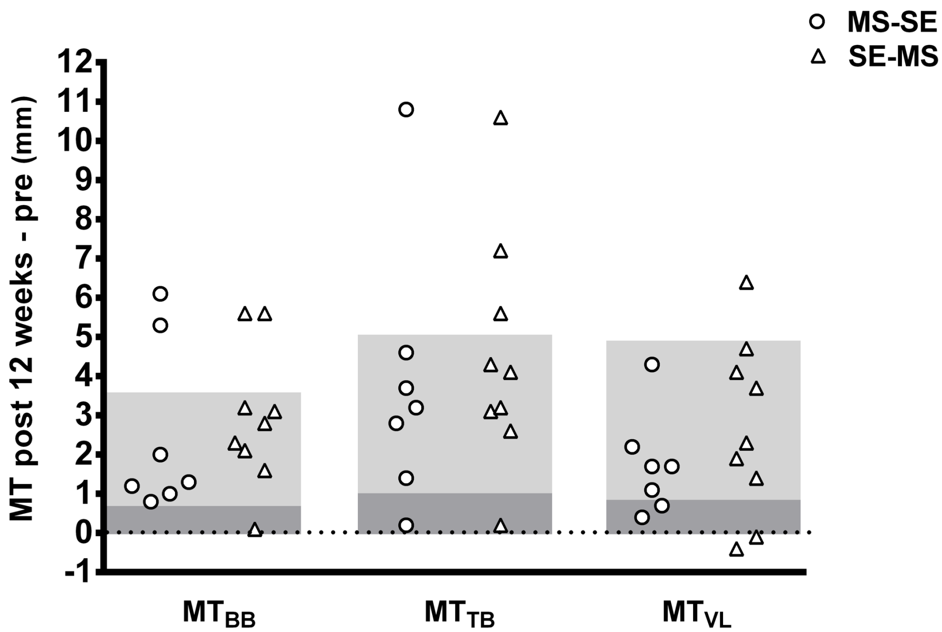

Figure 1. Univariate scatterplot with absolute differences from pre to week 12 in muscle thickness of the triceps brachii (MT_{TB}), biceps brachii (MT_{BB}) and vastus lateralis (MT_{VL}) in MS-SE (Maximal Strength-Strength endurance training) and SE-MS (Strength endurance – Maximal strength training) groups. Dark (non-responder) and light grey (small/moderate) indicate "cut-points" for responsiveness (see Methods).

Between-group ES (MS-SE vs. SE-MS): Effect size in absolute differences from pre to post six weeks between MS-SE vs. SE-MS was trivial ($1RM_{SQUAT}$ and MT_{VL}) or moderate ($1RM_{BENCH}$, MT_{BB}, MT_{TB}). In Δ post 12 weeks compared to pre all ES was trivial (d <0.2), except $1RM_{SQUAT}$ and MT_{VL} (moderate). Only Δ post six weeks compared to post six weeks in $1RM_{SQUAT}$ (favor to MS-SE) and MT_{VL} (favor to SE-MS) presented large ES (d = 1.19, IC 90% = 0.83 to 1.55) and (d = 1.60, IC 90% = 1.03 to 2.17), respectively.

Training Load: No significant differences between-groups were noted in any TLL and ITL variables (all $p > 0.05$) (Figure 2).

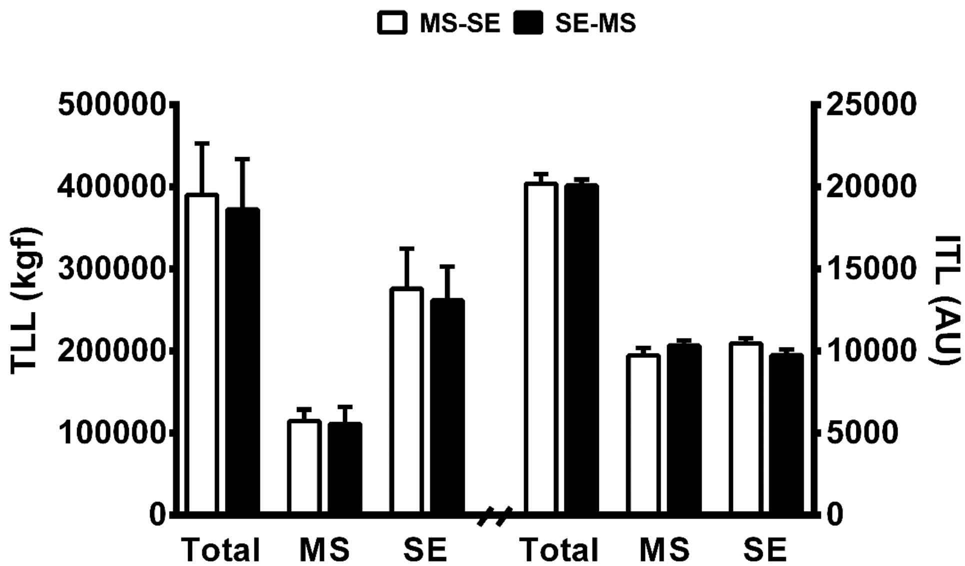

Figure 2. Accumulated total load lifted (TLL) and internal training load (ITL) of participants during the 12 weeks of training intervention (Total), 6 weeks of strength training (MS) and strength endurance training (SE). MS-SE = Maximal strength – strength endurance training group; SE-MS = Strength endurance – Maximal strength training group.

DISCUSSION

To the best of the authors' knowledge, this is the first investigation assessing the chronic effects of distinct order of RT cycles on strength and morphological adaptations in resistance-trained men. The main finding was that a maximal strength-strength endurance protocol is as efficient as a strength endurance-maximal strength one for increasing muscle strength and size, confirming the initial hypothesis. Although participants of the study presented a large training experience (4.6 ± 0.7 years), the intervention protocols adopted resulted in significant increases in all the dependent variables assessed. The large percentage increases observed might be attributed to the recreational level of the participants. Then, it can be suggested that higher-level resistance-trained participants would present increments of lower magnitude compared to those described by the current study.

For the $1RM_{BENCH}$, a significant increment was observed between pre and post twelve weeks for both experimental groups (MS-SE: 19.0%, SE-MS: 20.0%). In the first six weeks, however, only the group performing a maximal strength protocol presented a significant increase. These results were not observed in the group performing a strength endurance protocol though. Although both groups trained with a high intensity of effort (muscular concentric failure), such results can be explained by the higher loads adopted by the MS-SE group in this phase of the intervention. It has been previously reported that maximal dynamic strength increment seems to be largely affected by this training variable (7, 27, 28, 29). Additionally, adaptations obtained in the pre to post six-week phase were maintained in the post six to post twelve-week period, even when performing a strength-endurance protocol with lower loads.

For the $1RM_{SQUAT}$, a significant increase was observed for both groups between pre to post twelve-week period (MS-SE: 28.5%, SE-MS: 45.2%). Similar to the bench press results, a larger increase was observed in the period where a maximal strength protocol was performed, emphasizing the role of stimulus specificity observed in this outcome.

For muscle thickness, no statistical difference was observed between groups in any moment (pre, post six, and post twelve weeks) for the assessed muscle groups. A significant increase was observed in biceps and triceps brachii between the pre to post twelve-week period in both experimental groups. However, in the first six-week phase, only the group performing a strength endurance protocol showed a significant increment, which was not observed for the other experimental group (MS-SE). This result can be explained by the higher TLL and mechanical stress experienced during this intervention cycle. Indeed, a larger increase in muscle hypertrophy has been described as a result of performing training cycles with a higher TLL, independently of the manipulation of others training variables (e.g., intensity, frequency, rest) (4, 5, 13, 29, 30, 31, 32).

Given the large inter-individual variability generally seen in exercise studies, insight into each participants' responsiveness may represent an important tool when attempting to draw evidence-based inferences. The results of the individual analyses of MT showed that a large responsiveness was observed in SE-MS compared to MS-SE for MT_{TB} (33% vs. 14%, respectively) and MT_{VL} (11% vs. 0%, respectively). For MT_{BB}, however, a large responsiveness was noted in MS-SE compared to SE-MS (28% vs. 22%, respectively). Then, although both groups presented similar increases in muscle morphology outcomes, individual responses induced by distinct orders of training cycles might be muscle group-dependent. It is also interesting to note that participants in SE-MS were able to maintain their MT increases even when reducing total training volume during the Maximal Strength phase. Then, one can assume that the adoption of a higher load/low volume-RT protocol is sufficient to maintain the previously obtained morphological adaptations.

The analysis of TLL outcomes during RT trials is of great relevance since the increments in muscle strength and mass seem to be strongly influenced by this variable (13). No significant difference was observed between experimental groups in accumulated TLL (twelve-week intervention period). This result can be justified by the equated external loads implemented in the current experimental design. All participants performed both protocols (strength endurance and maximal strength), resulting in the same total mechanical stress by the two groups then. Initially, one could expect that the greater strength increments observed during the Maximal Strength phase would allow participants to mobilize higher loads during the Strength Endurance one. However, this hypothesis was not confirmed. Although speculative due to the high RT experience from the participants of the study, the adoption of a longer intervention period (and consequently higher magnitude-strength increments) could eventually induce distinct responses in such dependent variable.

Internal training load (ITL) is a useful tool to monitor physiological stress experienced by an individual during a training session/period (18). Such organic stress can be a determinant factor in relation to positive or negative adaptations or an index of increased performance, overtraining or injury (11). For accumulated ITL, no difference was observed between groups. In the present study, ITL was calculated by the product of the session time under tension by the rate of perceived exertion (RPE). A higher ITL score was observed when comparing the training cycles (strength endurance > maximal strength). Such result can be explained by the higher time under tension and volume (number of repetitions) observed in the strength endurance protocol, confirming the strong association between ITL and TLL (r = 0.73, p < 0.05) previously reported (21). Moreover, no difference was observed in session RPE between the two training protocols, suggesting that the intensity of effort seems to be the main factor influencing this variable, regardless of the load adopted (14).

It is important to note that the present study has some limitations. The small sample size affected the statistical power. As is the case in the majority of longitudinal RT studies, a high degree of inter-individual variability was noted among participants, which limited the ability to detect a significant difference in several outcome measurements. Despite this limitation, the analysis of the effect sizes and individual responsiveness through SWC provides a good basis for drawing inferential conclusions from the results. Additionally, a larger difference between groups induced by the adoption of a larger intervention period must not be discarded. Then, future studies with longer duration must be performed in order to clarify these findings. Lastly, these results must not be extrapolated to other populations, such as untrained individuals.

In conclusion, the findings of the present study suggest that the order of training cycles is not a critical factor for enhancing performance and morphological outcomes, as long as TLL is equated. Generally, recreationally resistance-trained individuals may experience significant and similar increases in muscle strength and size alternating different repetition zones (2-4RM and 10-12RM) with the same intensity of effort according to personal preferences or competitive demands. In addition, individual responses in muscle size increases may be dependent of specific muscle groups.

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