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Does Split-Body Resistance Training Routine Performed Two Versus Three Days Per Week Induce Distinct Strength and Morphological Adaptations in Resistance-Trained Men? A Randomized Longitudinal Study

Felipe Alves Brigatto[1], Júlio Benvenutti Bueno De Camargo[1], Yuri Benhur Machado[1], Moisés Diego Germano[1], Marcelo Saldanha Aoki[2], Tiago Volpi Braz[1], Charles Ricardo Lopes[1,3]

[1]Human Performance Research Laboratory, Human Movement Sciences Postgraduate Program, Methodist University of Piracicaba. Piracicaba, Brazil; [2]School of Arts, Sciences and Humanities, University of São Paulo. São Paulo, Brazil; [3]Adventist Faculty of Hortolândia. Hortolândia, Brazil

ABSTRACT

The purpose of this study was to investigate the chronic effects of training each muscle group through a split-body routine on 2 versus 3 days per week on muscle strength and morphological adaptations in recreationally resistance-trained men with the number of sets per muscle group equated between conditions. Twenty healthy men (28.8 ± 6.1 years [range 19 to 37 years]; 172.8 ± 5.1 cm; total body mass = 70.2 ± 7.4 kg; RT experience = 3.5 ± 0.8 years [range 2 to 5 years]; RT frequency = 4.4 ± 0.5 session·wk^{-1}) volunteered to participate in this study. Subjects were randomly assigned into 2 experimental groups: 2 sessions·wk^{-1} per muscle (G2x, n = 10), in which every muscle was trained twice a week with 9 sets/session, or 3 sessions·wk-1 per muscle (G3x, n = 10), in which every muscle was trained thrice a week with 6 sets/session. All other variables were held constant over the 8-week study period (training intensity: 8-12 maximum repetitions; rest intervals: 60 seconds between sets). No significant difference between conditions was observed for maximal strength in the back squat (G2x: Δ = 51.5%; G3x: Δ = 56.3%, p = 0.337) and bench press (G2x: Δ = 15.4%; G3x: Δ = 20.5%, p = 0.756), muscle thickness of the biceps brachii (G2x: Δ = 6.9%; G3x: Δ = 8.9%, p = 0.495), triceps brachii (G2x: Δ = 8.4%; G3x: Δ = 15.7%, p = 0.186), vastus lateralis (G2x: Δ = 11.2%; G3x: Δ = 5.0%, p = 0.082 and anterior quadriceps (rectus femoris and vastus intermedius) (G2x: Δ = 12.1%; G3x: Δ = 21.0%, p = 0.102). In conclusion, both G2x and G3x can result in significant increases in muscle strength and size in recreationally trained men.

Keywords: Resistance training frequency, muscle hypertrophy, maximal strength, volume.

INTRODUCTION

Increases in both muscle strength and size (i.e. hypertrophy) are considered specific adaptations of resistance training (RT), which may be enhanced by the proper manipulation of training variables, such as training frequency [1]. Generally, RT frequency refers to the number of sessions performed during a specific period, usually described on a weekly basis. In addition, training frequency can also be described as the number of sessions per week (sessions·wk^{-1}) in which the same muscle group is stimulated [2].

Individuals that aim to maximize hypertrophy usually adopt training routines with high volumes associated with long recovery periods (e.g. 48h). In this sense, practitioners use a split-body routine (SPLIT) that includes multiple exercises for a specific muscle group within a training session. Compared to full-body routines, the adoption of a SPLIT routine is usually justified by the fact that it may reduce the overall sets of a training session while increasing the number of sets per muscle group and also requiring a reduced time to be performed and a longer recovery period between sessions [3]. Moreover, higher training volumes within the same session would also elicit an increased intramuscular metabolic stress, which may enhance the hypertrophic response to the RT session [4].

However, studies comparing different RT frequencies in trained subjects, distributed into SPLIT versus full-body routines on a volume-equated basis (same number of sets per muscle group per week), have shown controversial results. Some of these studies reported no significant differences between higher (full-body) and lower frequencies (SPLIT) [5,6], while others demonstrated a potentially better hypertrophic effect for the full-body routine [2,7]. Indeed, systematic reviews with meta-analysis showed no significant difference between higher and lower frequency on a volume-equated basis for both muscle strength [8] and hypertrophy [9] outcomes.

Although it is well established that both higher and lower frequencies can generate substantial increases in muscle strength and morphological outcomes, only 7 studies have investigated the effects of different RT frequencies on morphological adaptations in trained subjects, using validated diagnostic imaging methods (e.g. ultrasound) to assess changes in muscle size [2,6,7,10–13]. Moreover, most of the studies that specifically investigated training frequencies of 2 versus 3 days per week employed whole body measures of muscle mass (e.g., dual-energy X-ray absorptiometry), which are not as sensitive for detecting subtle changes over time as site-specific measures, such as ultrasound or magnetic resonance imaging [14]. To the authors' knowledge, only one study investigated the effects of training the same muscle group twice versus thrice a week in trained subjects using validated diagnostic imaging methods [6]. In this study, in which SPLIT (2 sessions·wk-1) versus full-body (3 sessions·wk-1) routines were compared, both frequencies produced similar increases in muscular adaptations over 10 weeks [6]. In this sense, there is a paucity of research investigating the potential benefits of training muscle groups employing only SPLIT routines with frequencies of 2 versus 3 sessions·wk^{-1}.

Therefore, the purpose of the present study was to compare the effects of a SPLIT routine distributed into 2 versus 3 sessions·wk^{-1} per muscle group on muscle strength and morphological adaptations in recreationally resistance-trained men, with the number of sets per muscle group per week equated between conditions. It was hypothesized that the experimental group performing 3 weekly sessions/muscle group would present significantly greater muscular adaptations compared to the group training each muscle group on 2 weekly sessions.

METHODS

Approach to the problem

This was a randomized, longitudinal study in which participants were pair-matched according to baseline strength and then randomly assigned to 1 of the 2 experimental groups: 2 sessions·wk^{-1} per muscle group (G2x, n = 10), where every muscle group was stimulated in 2 weekly sessions with 9 sets/session; 3 sessions·wk^{-1} per muscle group (G3x, n = 10), where every muscle group was stimulated in 3 weekly sessions with 6 sets/session. All other RT variables (e.g., exercise performed, exercise order, range of repetitions, rest interval between sets and exercises, etc.) were maintained constant along the intervention period. The experimental period lasted 11 weeks: 1st week – familiarization period; 2nd week – pre-intervention period (baseline); 3rd-10th weeks

– training intervention period; 11th week – post-intervention period. The total load lifted (TLL) was calculated for every RT session in order to compare the accumulated external training load between the groups across the intervention period.

Testing was carried out during the pre and post-intervention periods for maximal voluntary muscle strength (one repetition maximum [1RM] test for bench press and parallel back squat exercises) and muscle thickness (MT) of the biceps brachii, triceps brachii, vastus lateralis and anterior quadriceps (rectus femoris and vastus intermedius). During the 1st week, volunteers attended to 2 familiarization sessions in the laboratory and reported having refrained from performing any exercise other than activities of daily living for at least 48-h before the first familiarization session. In the first session, volunteers were familiarized with 1RM tests. On the following day (24-h after), volunteers were familiarized with standard procedures adopted in all RT exercises, such as body position, cadence, range of motion, rest, etc. Additionally, subjects were trained and instructed to record their dietary intake.

Subjects

Twenty healthy men (28.8 ± 6.1 years [range 19 to 37 years]; 172.8 ± 5.1 cm; total body mass = 70.2 ± 7.4 kg; RT experience = 3.5 ± 0.8 years [range 2 to 5 years]; RT frequency = 4.4 ± 0.5 session·wk^{-1}) (Table 1) 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 difference of 0.75, an alpha level of 0.05, and a power (1–β) of 0.80 [15]. All subjects performed RT for a minimum of 3 days a week for at least 1 year and reported to regularly performing all exercises adopted during the intervention and in the strength tests for at least 1 year before initiating the study. Moreover, subjects were free from any existing musculoskeletal disorders and stated that they had not taken anabolic steroids or any other ergogenic aid that could increase muscle size during the previous year. Additionally, all subjects presented a minimum 1RM parallel back squat of 1.25x total body mass and a 1RM bench press of at least equal to total body mass [16]. This study was approved by the university research ethics committee (protocol 1.792.429); all subjects read and signed an informed consent document.

Training protocol

The RT protocol consisted of 9 exercises targeting each of the major muscle groups. Subjects were instructed to refrain from performing any additional resistance-type training during the study. The specific protocols for G2x and G3x are outlined in Table 2. The exercises were chosen based on the fact that they are commonly included in bodybuilding and strength-type RT programs [17]. The G2x weekly training consisted of 4 training sessions ($A_{routine}$ + $B_{routine}$ + $A_{routine}$ + $B_{routine}$), whereas the G3x weekly training consisted of 6 training sessions ($A_{routine}$ + $B_{routine}$ + $A_{routine}$ + $B_{routine}$ + $A_{routine}$ + $B_{routine}$). Each set involved 8-12 repetition-maximum (RM) with 60-s of rest afforded between sets and 120-s between exercises. In case of the target repetition range could not be performed within a given set (< 8 repetitions), load adjustments (5% to 10%) were

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

Variables	G2x (n=10)	G3x (n=10)	*p* value
Age (years)	28.0 ± 6.7	29.7 ± 5.9	0.422
Total Body Mass (kg)	67.7 ± 5.5	72.7 ± 8.5	0.163
Height (cm)	171 ± 5	174 ± 4	0.425
RT Experience (years)	3.3 ± 0.8	3.0 ± 0.8	0.512
RT Frequency (sessions·wk^{-1})	4.4 ± 0.5	4.5 ± 0.5	0.481
1RMBENCH ÷ Body Mass	1.3 ± 0.2	1.3 ± 0.2	0.662
1RMSQUAT ÷ Body Mass	1.7 ± 0.2	1.7 ± 0.3	0.604

Note. G2x = two sessions·wk^{-1} per muscle group; G3x = three sessions·wk^{-1} per muscle group; RT = resistance training; $1RM_{BENCH}$ ÷ Body Mass = one maximal repetition test in bench press exercise value relative to body mass; $1RM_{SQUAT}$ ÷ Body Mass = one maximal repetition test in parallel back squat exercise value relative to body mass.

Table 2. Training protocols.

	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday
G2x (n=10)	A_{rout} Bench press 5 sets Dumbbell flat fly 4 sets Cable triceps 4 sets Parallel back squat 5 sets Leg extension 4 sets	B_{rout} Lat pulldown 5 sets Straight-arm pull-down 4 sets Biceps curl 4 sets Seated leg curl 9 sets		A_{rout} Bench press 5 sets Dumbbell flat fly 4 sets Cable triceps 4 sets Parallel back squat 5 sets Leg extension 4 sets	B_{rout} Lat pulldown 5 sets Straight-arm pull-down 4 sets Biceps curl 4 sets Seated leg curl 9 sets	
G3x (n=10)	A_{rout} Bench press 3 sets Dumbbell flat fly 3 sets Cable triceps 3 sets Parallel back squat 3 sets Leg extension 3 sets	B_{rout} Lat pulldown 3 sets Straight-arm pull-down 3 sets Biceps curl 3 sets Seated leg curl 6 sets	A_{rout} Bench press 3 sets Dumbbell flat fly 3 sets Cable triceps 3 sets Parallel back squat 3 sets Leg extension 3 sets	Brout Lat pulldown 3 sets Straight-arm pull-down 3 sets Biceps curl 3 sets Seated leg curl 6 sets	A_{rout} Bench press 3 sets Dumbbell flat fly 3 sets Cable triceps 3 sets Parallel back squat 3 sets Leg extension 3 sets	B_{rout} Lat pulldown 3 sets Straight-arm pull-down 3 sets Biceps curl 3 sets Seated leg curl 6 sets

Note. G2x = two sessions·wk^{-1} per muscle group; G3x = three sessions·wk^{-1} per muscle group; A_{rout} = split routine A; B_{rout} = split routine B.

implemented in the next one. All sets were carried out to the point of momentary concentric muscular failure. The cadence of repetitions was carried out in a controlled fashion, with concentric and eccentric actions of approximately 1.5 s, for a total repetition duration of approximately 3-s. The external load was adjusted for each exercise, as needed, on successive sets to ensure that subjects achieve failure in the target repetition range. Participants reported a rating of perceived exertion (RPE) based on the repetitions in reserve (RIR) scale [18] of 9.5-10 for all sets and exercises across RT sessions.

Research assistants directly supervised all routines to ensure the adequate performance of the respective routines. Before the training intervention period, all subjects underwent 10RM testing (according to procedures established by Haff and Triplett [17]) to determine individual initial training loads for each exercise. Attempts were made to progressively increase the external loads lifted each week while maintaining the target repetition range. No injuries were reported and the adherence to the program was 100% for both groups.

Participants were instructed to maintain their usual nutritional habits and to avoid taking any supplements during the study period. Dietary nutrient intake was assessed by 24-h food recalls on 2 nonconsecutive weekdays and 1 day of the weekend. The subjects were instructed to record in detail the time of consumption, types and quantity of food preparations consumed during 24 h. The estimation of energy intake (macronutrients) was analyzed by NutWin software (UNIFESP, Sao Paulo, Brazil) during weeks 1, 4 and 8 of the intervention period (Table 3).

Maximal strength testing

Upper- and lower-body maximum strength were assessed by 1RM testing on the bench press ($1RM_{BENCH}$) and back squat ($1RM_{SQUAT}$) exercises. The testing was consistent with recognized guidelines [17]. Subjects performed sets of 1 repetition of increasing weight for 1RM determination. The external load was adjusted by ~5-10% in subsequent attempts until the subject was unable to complete 1 maximal muscle action. A 3- to 5-min rest was afforded between each successive attempt. All 1RM determinations were made within 5 attempts. $1RM_{BENCH}$ testing was conducted before the $1RM_{SQUAT}$ with a 20-min rest period separating tests. All testing sessions were supervised by the research team to achieve a consensus for success on each attempt. The test-retest intraclass correlation coefficient (ICC), coefficient of variation (CV) and the standard error of the measurement (SEM) calculated from the data collected during the familiarization period and the pre-intervention period (five days between the test-retest) for $1RM_{BENCH}$ were 0.989, 0.8% and 2.05 kg, respectively. The ICC, CV and SEM for $1RM_{SQUAT}$

Table 3. Estimated dietary nutrient intake for G2x and G3x (mean ±SD).

				ANOVA 3x2	
Variables	**Week 1**	**Week 4**	**Week 8**	**Time Effect *P* value**	**Time X Group Interaction *P* value**
Total (kcal)					
G2x	2497 ± 301	2505 ± 318	2621 ± 215	0.215	0.202
G3x	2518 ± 291	2552 ± 367	2539 ± 287	0.308	
Protein (g/kg^{-1})					
G2x	2.5 ± 0.5	2.6 ± 0.5	2.5 ± 0.4	0.214	0.188
G3x	2.4 ± 0.4	2.5 ± 0.4	2.4 ± 0.3	0.157	
Carbohydrate (g/kg^{-1})					
G2x	5.3 ± 0.4	5.3 ± 0.7	5.5 ± 0.4	0.202	0.242
G3x	5.0 ± 0.7	5.1 ± 1.0	5.0 ± 0.6	0.391	
Lipids (g/kg^{-1})					
G2x	0.7 ± 0.2	0.6 ± 0.1	0.7 ± 0.1	0.288	0.376
G3x	0.6 ± 0.2	0.6 ± 0.2	0.6 ± 0.2	0.329	

Note. G2x = two sessions·wk^{-1} per muscle group; G3x = three sessions·wk^{-1} per muscle group; Total (Kcal) = total kilocalories intake (3 recorded days' average); g/kg^{-1} = grams per kilogram of body mass.

were 0.990, 0.7% and 1.95 kg, respectively.

Muscle thickness assessments

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). MT dimensions were obtained by measuring the distance from the subcutaneous adipose tissue–muscle interface to the muscle-bone interface, according to methods used by Abe et al. [17]. Measurements were taken on the right side of the body at 4 sites: biceps brachii (MT_{BB}), triceps brachii (MT_{TB}), vastus lateralis (MT_{VL}) and anterior quadriceps (MT_{AQ}). Upper arm measurements were conducted while participants were standing. Afterward, participants laid supine on an examination table for measurements of the thigh muscles.

For the anterior and posterior upper arm, measurements were taken 60% distal between the lateral epicondyle of the humerus and the acromion process of the scapula; for the thigh muscles, measurements were taken at 50% of the distance between the lateral condyle of the femur and greater trochanter. To maintain consistency between pre- and post-intervention testing, each site was marked with henna ink (reinforced every week). All images were obtained 48-72 h before initiating the study and after the final training session [19]. All images were performed by an experienced researcher who was blinded to the RT protocol performed. The test-retest ICC for MT_{BB}, MT_{TB}, MT_{VL} and MT_{AQ} were 0.998, 0.996, 0.999 and 0.995, respectively. The CV for these measures were 0.6, 0.4, 0.6 and 0.7%, respectively. The SEM for these measurements were 0.42, 0.29, 0.41 and 0.40 mm, respectively.

Total load lifted

TLL (sets x repetitions x external load [kgf]) 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. The ΔTLL described the difference in the TLL between the 8th and 1st week of the training period (e.g. TLL at week 8 minus the TLL at week 1). Only repetitions performed through a full range of motion were included for analysis. The data were expressed in kilogram-force units (kgf).

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 assumed. To compare mean values of the baseline descriptive variables, ATLL and Δkgf (week 8 – week 1) between-groups (G2x vs. G3x), an unpaired 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 8) x two groups (G2x vs G3x). A repeated-measures ANOVA 2 x 2 was used to compare the time effect in MT_{BB}, MT_{TB}, MT_{VL}, MT_{AQ} (pre and post-week 8) and two groups. A repeated-measures ANOVA 2 x 3 (interaction groups and time [weeks 1, 4 and 8]) was used to compare the food intake variables (total kcal, proteins, carbohydrate and lipids). 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 ($\eta^2 p$), with < 0.06, 0.06 - 0.14 and > 0.14 indicating a small, medium, and large effect, respectively. The effect sizes (ES) of the absolute differences (pre vs post 8 weeks) in raw values of the variables using the standardized difference based on Cohen's *d* units by means (*d* value) [20] were also adopted. 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. If the 90% confidence limits (95% CI) overlapped, small positive and negative values for the magnitude were deemed unclear; otherwise, that magnitude was deemed to be the observed magnitude [21]. All analyses were conducted in SPSS-22.0 software (IBM Corp., Armonk, NY, USA). The adopted significance was $p < 0.05$. The figures were formatted in GraphPad Prism version 6.0 software (La Jolla, CA, USA) following the assumptions for continuous data.

RESULTS

No significant difference was noted between groups for any of the baseline measurements (all $p > 0.05$ [Table 1]). There was no significant difference in any dietary intake variables (total kcal, proteins, carbohydrates and lipids) either within- or between-groups over the course of the study (all $p > 0.05$ [Table 3]).

Muscle strength

A significant main effect of time ($F_{1,18}$ = 15.603, p = 0.001, η^2p = 0.464), but not group x time interaction ($F_{1,18}$ = 0.100, p = 0.756, η^2p = 0.006), was observed for $1RM_{BENCH}$. There was a significant main effect of time ($F_{1,18}$ = 230.872, p = 0.001, η^2p = 0.928) but not group x time interaction ($F_{1,18}$ = 0.973, p = 0.337, η^2p = 0.051) for $1RM_{SQUAT}$ (Table 4). The effect size in absolute differences post 8 weeks - pre was moderate between G2x vs G3x in $1RM_{BENCH}$ (d = 0.85, 90%CI = 0.48 to 1.22) and $1RM_{SQUAT}$ (d = 0.44, 90%CI = 0.00 to 0.88) (Figure 1).

Muscle thickness

A significant main effect of time ($F_{1,18}$ = 16.798, p = 0,0001, η^2p = 0.483), but not group x time interaction

Table 4. Pre- vs. Post-8 weeks Muscle Strength measures (mean ±SD).

Variables	Pre	Post 8 weeks	Δ%	MD [95%CI]	time *P* value	time*group *P* value
$1RM_{BENCH}$ (kg)						
G2x	91 ± 15	105 ± 15a	15.4	14 [9 to 19]	0.001	0.756
G3x	91 ± 16	110 ± 13a	20.5	19 [13 to 25]	0.001	
$1RM_{SQUAT}$ (kg)						
G2x	117 ± 19	178 ± 19a	51.5	61 [48 to 74]	0.001	0.337
G3x	122 ± 32	191 ± 27a	56.3	69 [47 to 91]	0.001	

Note. G2x = two sessions·wk^{-1} per muscle group; G3x = three sessions·wk^{-1} per muscle group; $1RM_{BENCH}$ = one maximal repetition test in bench press exercise; $1RM_{SQUAT}$ = one maximal repetition test in parallel back squat exercise; MD = Mean Difference and 95% Confidence Interval. a Significantly greater than the corresponding pre-intervention value (P < 0.05).

Table 5. Pre and Post 8 weeks- Muscle Morphology measures (mean ±SD).

Variables	Pre	Post 8 weeks	Δ%	MD [95%CI]	time *P* value	time*group *P* value
MT_{BB} (mm)						
G2x	31.8 ± 5.2	34.0 ± 4.4a	6.9	2.2 [1.0 to 3.4]	0.027	0.495
G3x	34.7 ± 4.9	37.8 ± 6.0a	8.9	3.1 [1.9. to 4.3]	0.003	
MT_{TB} (mm)						
G2x	32.8 ± 6.9	35.5 ± 6.3a	8.4	2.7 [2.1 to 3.3]	0.001	0.186
G3x	26.4 ± 9.7	30.6 ± 9.2a	15.7	4.2 [3.3 to 5.1]	0.0001	
MT_{VL} (mm)						
G2x	35.3 ± 8.6	39.3 ± 10.1a	11.2	4.1 [3.3 to 4.9]	0.0001	0.082
G3x	32.4 ± 7.9	34.0 ± 7.7a	5.0	1.6 [0.7 to 2.5]	0.035	
MT_{AQ} (mm)						
G2x	33.0 ± 9.4	37.0 ± 10.2 a	12.1	4.1 [3.4 to 4.8]	0.0001	0.102
G3x	29.0 ± 10.0	35.1 ± 10.1a	21.0	6.1 [4.9 to 7.3]	0.0001	

Note. G2x = two sessions·wk^{-1} per muscle group; G3x = three sessions·wk^{-1} per muscle group; 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; MT_{AQ} = muscle thickness of the anterior quadriceps muscle; MD = Mean Difference and 95% Confidence Interval. a Significantly greater than the corresponding pre-intervention value (p < 0.05).

($F_{1,18}$ = 0.485, p = 0.495, η^2p = 0.026) was observed for MT_{BB}. There was a significant main effect of time ($F_{1,18}$ = 49.950, p = 0.001, η^2p = 0.723), but not group x time interaction ($F_{1.,18}$ = 1.890, p = 0.186, η^2p = 0.095) for MT_{TB}. A significant main effect of time ($F_{1,18}$ = 30.876, p = 0.001, η^2p = 0.632), but not group x time interaction ($F_{1,18}$ = 5.425, p = 0.082, η^2p = 0.232) was observed for MT_{VL}. There was a significant main effect of time ($F_{1,18}$ = 69.037, p = 0.001, η^2p = 0.793), but not group x time interaction ($F_{1,18}$ = 2.977, p = 0.102, η^2p = 0.142), was observed for MT_{AQ} (Table 5). The effect size in absolute differences post 8 weeks - pre was moderate between G2x vs G3x in MT_{BB} (d = 0.31, 90% CI = 0.03 to 0.59), MT_{TB} (d = 0.61, 90% CI = 0.11 to 1.11), MT_{VL} (d = -0.60, 90% CI = -1.05 to -0.15) and MT_{AQ} (d = 0.77, 90% CI = 0.34 to 1.20) (Figure 1).

Total load lifted

No significant effect for ATLL (p = 0.057) was observed between groups (Figure 2A). No significant effect of groups for delta absolute differences of the TLL in the week 8 minus week 1 was observed (p = 0.160; G2x = 28% vs G3x = 29%) (Figure 2B).

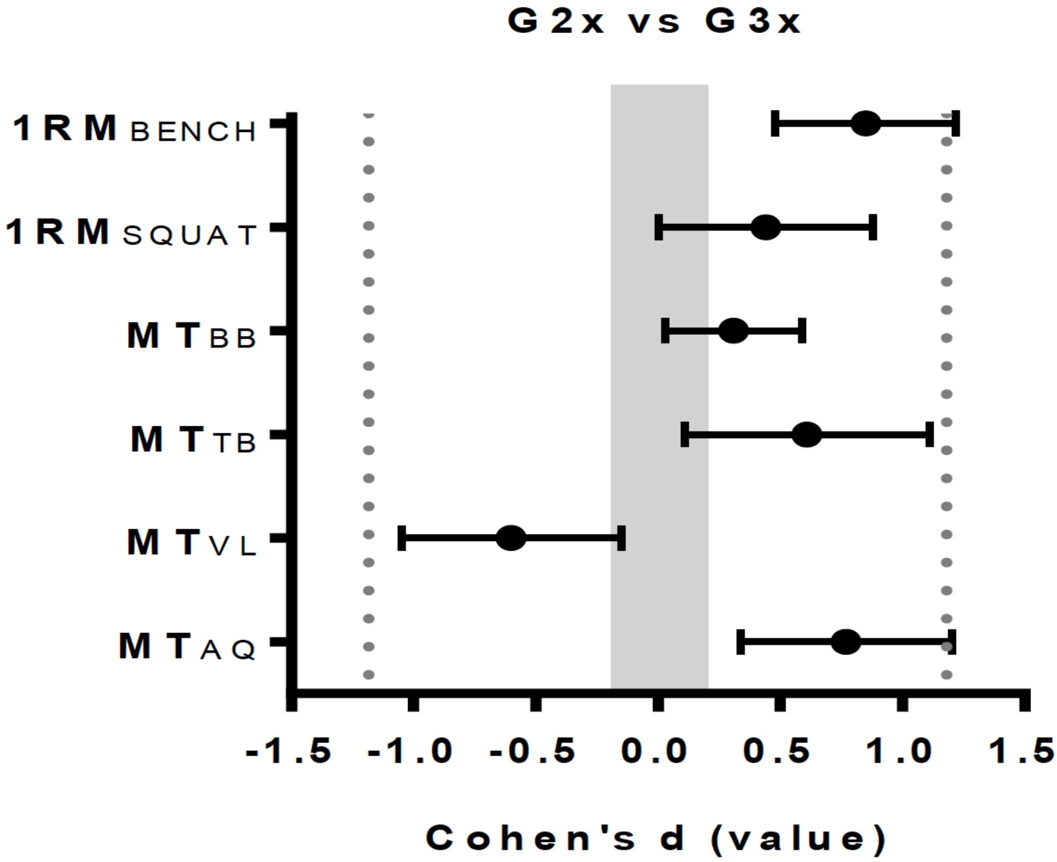

Figure 1. Comparison of groups G2x (2 sessions per week) and G3x (3 sessions per week) in $1RM_{BENCH}$, $1RM_{SQUAT}$, muscle thickness of the biceps brachii (MT_{BB}), triceps brachii (MT_{TB}), vastus lateralis (MT_{VL}) and anterior quadriceps (MT_{AQ}) muscles. The Cohen´s of effect size (ES) principle ± 90% confidence intervals was used to compare the absolute differences of the variables in the post 8 weeks – pre (raw values). Trivial areas were gray bar (d < 0.2). Gray dashed line are ES moderated upper limits

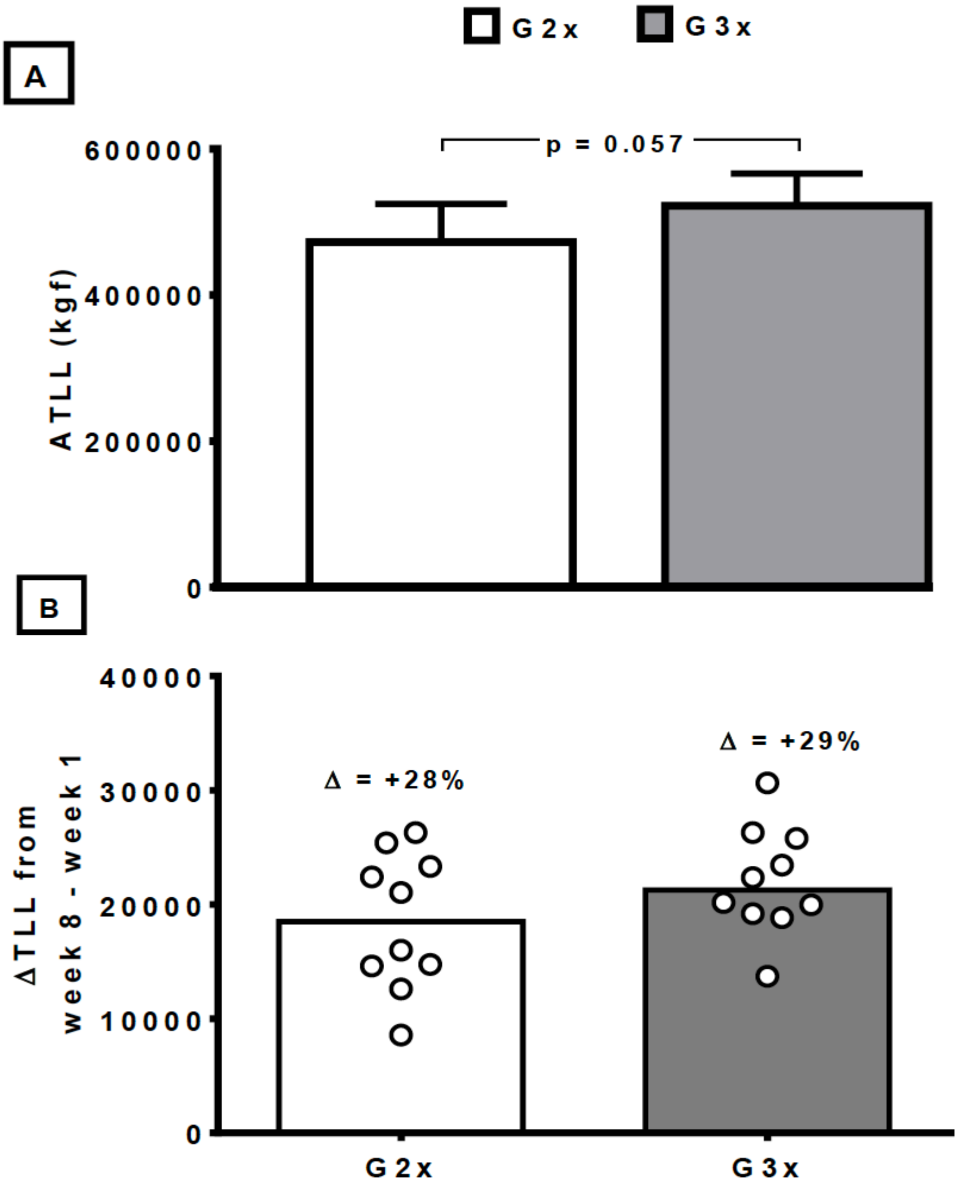

Figure 2. Weekly accumulated total load lifted (ATLL) of subjects during the 8-weeks of intervention training (2A). Delta (Δ) absolute and relative (%) differences of the TLL (kgf) in the week 8 minus week 1 (2B).

DISCUSSION

This is the first study to assess the chronic effects of a SPLIT routine performed 2 vs 3 days per week on muscle strength and morphological adaptations in recreationally trained men. The main finding of the present study was that adopting SPLIT routines twice a week is as efficient as training thrice a week to promote increases in maximal strength and hypertrophy over an 8-week program.

Both G2x and G3x elicited significant increases in maximal dynamic strength of both upper ($1RM_{BENCH}$: 15.4% and 20.5%, respectively) and lower limbs ($1RM_{SQUAT}$: 51.5% and 56.3%, respectively). No statistical difference was observed between conditions and the ES differences were moderate (d = 0.85) and small (d = 0.44), favoring G3x for $1RM_{BENCH}$ and $1RM_{SQUAT}$, respectively, suggesting a meaningful difference in the results. These results are in line with several studies that observed no difference between groups regarding muscle strength adaptations when comparing frequencies of 1 vs 2 [10,11,13]; 1 vs 3 [2,22]; 2 vs 3 [6]; 2 vs 4 [23]; 1 vs 5 [5,7] and 3 vs 6 sessions·wk^{-1} per muscle [12,24] in resistance-trained men. Moreover, our findings essentially corroborate recent meta-analytic data showing that under an equated volume condition, increasing training frequency did not result in additional maximal strength increases [8]. These findings are somewhat counterintuitive, as motor learning theory dictates that practicing a given exercise more frequently leads to better skill acquisition, conceivably through neural enhancements [25].

The present study adopted a high volume RT-protocol (18 weekly sets per muscle) since previous findings have reported a dose-response relationship between RT volume and both muscle strength [26] and hypertrophy [27]. Thus, according to the current findings, it seems that the weekly RT volume is more important than RT frequency for promoting muscle strength adaptations in recreationally trained men. In this sense, it seems plausible to suggest that when a high weekly RT-volume is adopted, a reduced neural advantage of the higher training frequency is observed.

Regarding MT, no significant between-groups difference was observed. Lasevicius et al. [6] compared SPLIT (two sessions·wk^{-1}) versus full-body (three sessions·wk^{-1}) routines over a 10-week period and reported no significant difference in muscle hypertrophy between both groups. The present study expands on previous findings by providing evidence that frequencies of 2 vs 3 sessions·wk-1 resulted in similar muscle hypertrophy even when the same SPLIT routine was employed in a volume-equated condition. Moreover, these results seem to be in line with several studies that observed no between-groups difference in muscle hypertrophy when comparing frequencies of 1 vs 2 [10,11,13]; 2 vs 4 [23]; 1 vs 5 [5]; 3 vs 6 sessions·wk-1 per muscle group [12,24]. Interestingly, although the findings of the current study essentially reflect the results of a previous meta-analysis [9], it also differs from a previous investigation from our research group that reported that muscle hypertrophy was potentiated when adopting a higher training frequency [7]. Some methodological differences must be acknowledged in order to compare this distinct results. Firstly, a higher training frequency for each muscle group (5 sessions weekly sessions) was adopted in Zaroni et al. [7] compared to the present study. Secondly, the training experience of the participants differed between the current investigation and Zaroni et al. [7] (3.5 vs 6.4 years, respectively). Therefore, one can suggest that the eventual effects of increasing training frequency on muscle morphology may be somehow modulated by the training experience of the subject. In addition, a significant difference in ATLL between groups was reported in Zaroni et al. [7] but not in the present study, suggesting that higher training frequency only leads to maximized hypertrophic adaptations when resulting in a significantly higher ATLL compared to a lower frequency training protocol.

The absence of differences in MT responses between groups observed in the present study may be partially justified by the fact that the ΔTLL was similar between G2x and G3x (28% vs 29%, respectively). Indeed, previous data from our research group [28] and others [29] reported that under similar load progression-conditions, hypertrophic adaptations do not differ between experimental groups, even when a significant difference is observed in ATLL. In this sense, although additional studies are warranted, it can be suggested that a proper magnitude of load progression seems to be more relevant than manipulating RT-frequency for promoting morphological adaptations in intermediate trained subjects.

Interestingly, it should also be noted that a small to moderate, but potentially meaningful ES difference (range 0.31 to 0.77), was observed in favor of G3x vs G2x for 3 of the 4 MT sites assessed (Figure 1). These findings suggest a potential hypertrophic benefit for the higher training frequency. Future studies using direct measurements of hypertrophy (i.e. ultrasound, magnetic resonance imaging or computed tomography) and adopting a clinical/practical statistical approach are required to provide further insight into this topic.

The present study has some limitations. Firstly, the study period lasted only 8 weeks. Although this duration was sufficient to result in a significant increase in muscular strength and thickness in both groups, it is conceivable that results between groups could have diverged over a longer time frame. Secondly, the small sample size might have affected statistical power. As is the case in the majority of longitudinal RT studies, a high degree of inter-individual variability was noted among subjects, which limited the ability to detect a significant difference in several outcome measures. Despite this limitation, the analysis of effect sizes provides a good basis for drawing inferential conclusions from the results. Finally, the findings of the present study are specific to young recreational-level trained men and cannot be extrapolated to other populations.

CONCLUSIONS

The present study suggests that training each muscle group through a SPLIT routine performed in either 2 or 3 sessions·wk^{-1} are both viable strategies to increase muscle strength and hypertrophy in recreationally resistance-trained men when volume is equated between training conditions. The greater effect size favoring G3x for some outcome measures suggests a potential benefit to a 3-weekly training schedule and may be considered by strength and conditioning coaches when prescribing RT programs. It is possible that these benefits may be related to distributing the same weekly RT volume over a greater number of training sessions, which may attenuate accumulated intra-session muscle fatigue. Moreover, personal preferences and available time to perform the training sessions must be taken into account when specifically manipulating training frequency.

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