Rest-pause and drop-set training elicit similar strength and hypertrophy adaptations compared to traditional sets in resistance-trained males

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Complete List of Authors:	<p>Enes, Alysson; Federal University of Parana, Metabolism, Nutrition and Resistance Training Research Group (GPMENUTF), Department of Physical Education</p> <p>Alves, Ragami; Federal University of Parana, Metabolism, Nutrition and Resistance Training Research Group (GPMENUTF), Department of Physical Education</p> <p>Schoenfeld, Brad; Exercise Science Department, CUNY Lehman College, Bronx, New York, USA</p> <p>Oneda, Gustavo; Federal University of Parana, Exercise Performance Research Group (CEPEFIS), Department of Physical Education</p> <p>Perin, Samuel; Federal University of Parana, Metabolism, Nutrition and Resistance Training Research Group (GPMENUTF), Department of Physical Education</p> <p>Trindade, Thiago; Universidade Católica de Brasília, Graduation Program on Physical Education</p> <p>Prestes, Jonato; Catholic University of Brasilia, Physical Education</p> <p>Souza-Junior, Tacito P.; Federal University of Parana, Metabolism, Nutrition and Resistance Training Research Group (GPMENUTF), Department of Physical Education; Appalachian State University, Health and Exercise Science</p>
Novelty bullets: points that summarize the key findings in the work:	Rest-pause elicited a slightly superior benefit for strength adaptations compared to traditional resistance training., Resistance training systems do not promote superior hypertrophic adaptations when total training volume is equalized., Muscle thickness in distal portion of thigh are similar to baseline. Although modest, effect sizes tended to favor rest-pause.
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Rest-pause and drop-set training elicit similar strength and hypertrophy adaptations compared to traditional sets in resistance-trained males

Alysson Enes¹, Ragami C. Alves¹, Brad J. Schoenfeld⁴, Gustavo Oneda², Samuel C. Perin¹, Thiago B. Trindade³, Jonato Prestes³, Tácito P. Souza-Junior¹

¹Metabolism, Nutrition and Resistance Training Research Group (GPMENUTF), Federal University of Paraná (UFPR). Curitiba - PR, Brazil;

²Exercise Performance Research Group (CEPEFIS), Federal University of Paraná (UFPR). Curitiba - PR, Brazil;

³Graduation Program in Physical Education, Catholic University of Brasilia (UCB). Brasília - DF, Brazil;

⁴Department of Health Sciences, CUNY Lehman College. Bronx - NY, USA.

***corresponding author:** Alysson Enes. Metabolism, Nutrition and Resistance Training Research Group (GPMENUTF), Federal University of Paraná, Brazil. Rua Cel. Francisco H. dos Santos, 210, Department of Physical Education, Federal University of Paraná, Zip Code: 81531-980, Curitiba, Paraná, Brazil. Mail: alysson.enes@hotmail.com

Contact information (e-mails) for other authors

Ragami C. Alves (ragami1@hotmail.com)

Brad J. Schoenfeld (bradschoenfeldphd@gmail.com)

Gustavo Oneda (gut.oneda@gmail.com)

Samuel C. Perin (scperin@gmail.com)

Thiago B. Trindade (ttrindade@me.com)

Jonato Prestes (jonatop@gmail.com)

Tácito P. Souza-Junior (tacitojr2009@hotmail.com)

ABSTRACT

The present paper aimed to compare the effect of drop-set (DS) and rest-pause (RP) systems versus traditional resistance training (TRT) with equalized total training volume on maximum dynamic strength (1RM) and thigh muscle thickness (MT). Twenty-eight resistance-trained males were randomly assigned to either RP ($n = 10$), DS ($n = 9$) or TRT ($n = 9$) protocols performed twice a week for 8 weeks. 1RM and MT of the proximal, middle and distal portions of the lateral thigh were assessed at baseline and post intervention. A significant time $\times$ group interaction was observed for 1RM ($P = 0.025$) in the barbell back squat after 8-weeks. Post hoc comparisons revealed that RP promoted higher 1RM than TRT ($P = 0.001$); no statistical differences in strength were observed between the other conditions. A significant main effect of time was revealed for MT at the proximal ($P = 0.0001$) and middle ($P = 0.0001$) aspects of the lateral thigh for all training groups; however, the distal portion did not show a time effect ($P = 0.190$). There were no between-group interactions for MT. Our findings suggest that RP promotes slightly superior strength-related improvements compared to TRT, but hypertrophic adaptations are similar between conditions.

Novelty bullets

- Rest-pause elicited a slightly superior benefit for strength adaptations compared to traditional resistance training.
- Resistance training systems do not promote superior hypertrophic adaptations when total training volume is equalized.
- Muscle thickness in distal portion of thigh are similar to baseline. Although modest, effect sizes tended to favor rest-pause.

Keywords: muscle thickness; rest-pause; drop-set; skeletal muscle hypertrophy; muscle strength; resistance training.

INTRODUCTION

Resistance training (RT) is commonly prescribed as an interventional strategy to increase muscle strength and hypertrophy (Ratamess et al. 2009). Current theory proposes that manipulation of RT variables (e.g. volume, intensity, exercise order, time under tension and rest interval) can maximize these adaptations (Kraemer and Ratamess, 2004). In particular, the use of different RT systems is commonly recommended for resistance-trained individuals to avoid possible ceiling effects on muscular adaptations (Krzysztofik et al. 2019).

In addition to traditional resistance training (TRT), two of the most common systems employed by practitioners include drop-sets (DS) and rest-pause (RP) (Angleri et al., 2017; Korak et al., 2017). TRT is characterized by multiple sets performed with the same load taking prescribed inter-set rest intervals. DS training involves performing a set of an exercise to volitional fatigue with a given load, followed immediately by a decrease in load (~20%), thereby allowing performance of additional repetitions until concentric failure (Krzysztofik et al. 2019; Angleri et al. 2020). RP training employs short or prolonged intervals among repetitions within a set with a fixed repetition range at a fixed load (40-80% of 1RM). For example, if an individual cannot perform a specific number of repetitions at a given load, short (10-20 s) intra-set rest intervals are inserted to allow completion of the set (Prestes et al. 2019; Angleri et al. 2020). Objective longitudinal evidence is lacking as to whether RP and DS elicit superior muscular adaptations compared to TRT.

Some researchers have speculated that the use of different RT systems may create a favorable anabolic milieu that could enhance muscular gains (Schoenfeld, B. 2011; Fink et al. 2018; Ozaki et al. 2018; Prestes et al. 2019). For example, DS increases metabolic stress due to the high number of repetitions performed consecutively until

concentric failure (Fink et al. 2018; Ozaki et al. 2018). Moreover, RP may help to maximize mechanical stress by prolonging intraset time under tension at high-loads (Marshall et al. 2012; Prestes et al. 2019). The heightened levels of mechanical tension (i.e. high time under tension associated at high-loads) and metabolic stress (i.e. muscle metabolite accumulation, muscle hypoxia and alterations in local myogenic factors) produced by these alternative training systems could lead to improvements in muscle hypertrophy and/or muscle strength via a variety of mechanisms such as increased muscle fiber recruitment, altered myokine release and cell swelling (Marshall et al. 2012; Schoenfeld, B. 2013; Fink et al. 2018; Ozaki et al. 2018; Prestes et al. 2019; Hirono et al. 2020). This paper aimed to compare the effects of volume-equated RP, DS, and TRT on muscle strength and hypertrophy in resistance-trained males. Based on current evidence that RT systems can induce a greater magnitude of metabolic and mechanical responses than TRT, we hypothesized that RP and DS systems would elicit greater muscular adaptations when compared with TRT.

METHODS

Participants

The sample power was calculated by the software *G*Power* 3.1 for F family (ANOVA) to determine the number of participants at an *a priori* power of 0.80, alpha = 0.05, effect size of 0.35 and a correlation among repeated measures of 0.5 (Beck, 2013). The dependent variables used for sample size estimation were muscle strength and muscle thickness. The power analysis indicated that 24 individuals were required to meet the target objectives. After initial assessments, twenty-eight trained males (DS = 9; RP = 10; TRT = 9) were deemed eligible for participation. The inclusion criteria were as follows: a) age between 18-30 years; b) minimum barbell squat relative strength of 1.25 x body mass; c) negative responses on all items of the Physical Activity

Readiness Questionnaire; d) at least two years of experience with RT routines and previous experience with the RT systems used in the present study; e) free from creatine supplementation for at least 6 months. The following criteria were considered for exclusion: a) self-report of existing musculoskeletal injuries; b) self-report of continuous use of any substance that could alter muscular adaptations (e.g. anti-inflammatory drugs, anabolic androgenic steroids, etc.). This study was approved by the local ethics committee (protocol n° 030/09) and all procedures were in accordance with the Declaration of Helsinki. All participants were informed of the purpose and experimental procedures, and all signed a written informed consent form prior to their participation.

Study design

The study began with anthropometric assessments, dietary intake records and quadriceps muscle thickness (MT) assessments for each participant. Multifrequency bioelectrical impedance (InBody 120, Biospace, USA) was used to assess body mass and body fat, and a stadiometer (W200/5, Welmy®, Brazil) was used to assess height to the nearest 0.1cm. To minimize the influence of previous experience with maximal dynamic strength testing (Dias et al. 2005) we conducted a familiarization session for participants' 1-repetition maximum (1RM) at least 24 hours before initial 1RM testing. The familiarization session consisted of an explanation about the test and the technical standards for each exercise, as well as answering any questions from the participants. After this explanation, participants performed a specific low-load warm-up on the barbell back squat, followed by 2 sets of 1 submaximal repetition on the barbell back squat with a self-selected heavy load.

24-48 hours after the familiarization session, we conducted two separate 1-RM assessments separated by 48-72 hours. MT measurements were performed at least 72h after 1-RM testing. To avoid heterogeneity at baseline, we randomized participants into the experimental groups based on initial maximum dynamic strength capacity. After initial assessment, participants performed an 8-week training program carried out twice a week, for a total of 16 training sessions. After completing the intervention, we conducted MT and 1-RM assessments in the same manner as described at baseline. Dietary intake was collected every four weeks by a certified nutritionist throughout the intervention.

Maximum dynamic strength (1RM)

We determined initial loads according to percentages of participants 1RM for each exercise. Testing was conducted for each exercise at baseline, in the same exercise order as performed in the training program. Given that the purpose of the study was to investigate the effects of RT systems on lower-limb muscle strength, we only assessed barbell back squat 1RM post-intervention. Testing for 1RM was carried out as follows: Participants performed a general warm-up (5 min at 6km.h⁻¹ on a treadmill) followed by a specific warm-up of 2 sets of 8 and 3 repetitions at an estimated load of 10- and 6-RM, respectively. 1RM attempts began 3 minutes after performance of the specific warm-up. Participants received specific instructions regarding exercise technique (e.g. barbell back squat must be executed to a minimum of 90° of knee joint flexion), which was monitored by the research team. Load was increased by ~5% for each successful attempt, with a 1-RM load determined within five attempts. A 3 to 5 minute rest period was provided between attempts and exercises (Brown and Weir, 2001). We used the highest value between the two 1-RM tests at both pre- and post-intervention for our analysis. The coefficient of variation (CV), standard error of measurement (SEM), and

intraclass correlation coefficient (ICC) between two 1-RM sessions for each exercise performed 48-72h apart were as follows: barbell back squat (CV = 2.5%; SEM = 3.13kg; ICC = 0.97), 45° leg press (CV = 3.73%; SEM = 11.0kg; ICC = 0.94), seated knee extension (CV = 3.65%; SEM = 5.7kg; ICC = 0.88), stiff-leg deadlift (CV = 3.95%; SEM = 4.85kg; ICC = 0.87), and seated knee flexion (CV = 4%; SEM = 5.12kg; ICC = 0.92). The minimum detectable difference (MD) for the 1-RM barbell back squat was 8.68kg.

Muscle thickness (MT)

We used B-mode ultrasound (ECO3, Chison Medical Imaging Ltd., Jiang Su Province, China) with a 5-MHz linear transducer to obtain MT measurements of the proximal (30%), middle (50%) and distal (70%) portions of lateral thigh (combination of the vastus lateralis and vastus intermedius) (Fig. 1), considered as the distance between the greater trochanter and lateral condyle of the femur, starting at the greater trochanter (Abe et al. 2000). The dominant lower-limb was assessed, as determined by asking participants which leg they kick a ball with. All participants remained relaxed with the knees slightly flexed during image acquisition. Prior to imaging, they remained supine for 20 min to ensure proper fluid redistribution in the lower body musculature. A trained ultrasound technician, blinded to group allocation, applied a generous amount of water-soluble transmission gel to each measurement site. Transverse images were obtained by placing the transducer on the skin while taking care not to depress the skin. When a satisfactory image was obtained, it was saved to hard drive with MT measured as the distance between the internal border of the superficial aponeurosis of the vastus lateralis and external border of the femur. Participants were instructed not perform any strenuous exercise for at least 72h prior to ultrasound imaging to avoid the potential influence of muscle swelling on MT. All images were captured in duplicate and

measurements were averaged to obtain a final value; if the inter-image measurements showed a difference greater than 10%, then a third image was taken and averaged with the closest value (Schoenfeld et al. 2015). Considering the difference between two ultrasound images was less than 10%, the average between the two MT values was used for our analysis. CV, SEM, ICC, and MD between muscle thickness measurements for each thigh segments were as follows: Proximal: 0.77%, 0.30mm, 0.98 and 0.81mm, respectively; Middle: 0.64%, 0.29mm, 0.98 and 0.80mm, respectively; Distal: 0.54%, 0.21mm, 0.97 and 0.59mm, respectively.

****INSERT FIGURE 1 NEAR HERE****

Dietary intake

To assess the potential confounding effects of nutrition on study outcomes, participants completed a three-day, nonconsecutive dietary intake record (including a weekend day) preceding the intervention and then at the mid-point and conclusion of the study period. Total energy and macronutrient intake were calculated using nutritional software (Avanutri, 3.1.4 version, Rio de Janeiro, Brazil). To enhance accuracy of data, a certified nutritionist evaluated the dietary intake and helped participants to estimate their food and drink portions. The nutritionist was blinded to group allocations. All participants were instructed to maintain their habitual dietary intake during our experimental protocol.

Training sessions

Training sessions were performed at the same time of the day. Participants were instructed to have a meal 2h before each training session. Prior to each training session, a general (treadmill) and specific (barbell back squat) warm-up was performed in the same manner of 1RM tests. All training sessions were performed in the following exercise order: barbell back squat, 45° leg press, seated knee extension, stiff-leg deadlift and seated knee flexion. Table 1 shows the exercise variables specific to each protocol.

****INSERT TABLE 1 NEAR HERE****

Total training volume (TTV) was calculated as the product of sets, repetitions and load (kg) ($TTV = \text{sets} \times \text{repetitions} \times \text{load}$). We considered a single set to calculate TTV when participants performed 16 repetitions (10+6, first and second part of each set, with or without intraset rest interval or load maintenance) in DS or RP and 12 repetitions in each set on TRT (Schoenfeld et al., 2019). Repetition volume was equalized between groups (48 repetitions for barbell back squat, 45° leg press, seated knee extension, and 30 repetitions for stiff-leg deadlift and seated knee flexion in each training session). Importantly, slight differences in %1RM (i.e. 75% for DS and RP and 70% for TRT) were established in an attempt to balance possible daily and weekly fluctuations in muscle strength by having participants reach or stay close to muscle failure within the prescribed number of repetitions, ensuring the integrity of each training system. If a participant could not achieve the prescribed number of repetitions, he received a slight assistance on the final 1-2 repetitions to complete the target number of repetitions for that set. A certified strength and conditioning professional supervised all training sessions. Load was increased by 5% in the fifth week. Participants were instructed to maintain a repetition cadence of 1:0:2:0 s (1 s for the concentric action

and 2 s for the eccentric action without pausing in the transition phases) as monitored by the supervising researcher. RT systems were executed only in the barbell back squat, 45° leg press and seated knee extension. All participants performed the stiff-leg deadlift and seated knee flexion exercises in the same manner (3x10 reps at 70%1RM; 120s rest between sets) regardless of the training system. We included exercises specific to the lower body posterior chain in an attempt to replicate training routines commonly executed by trained individuals, and thus avoid potential dropouts. To this end, there were no dropouts during our experimental protocol.

Statistical Analysis

Data normality was assessed by the Shapiro-Wilk test. Levene's test was used to assess homogeneity of variances. After confirming data normality, the one-way analysis of variance (ANOVA) was used to detect possible differences in total training volume. A two-way repeated measures ANOVA (time x group) was used to identify possible interactions for dietary intake. To eliminate the possible influence of baseline scores on training outcomes, an analysis of covariance (ANCOVA) was employed with baseline values used as a covariate to identify potential time x group interactions. To determine if observed changes could be considered meaningful, we assessed the minimum detectable difference, using the following equation, for muscle strength and muscle thickness measures at each site (Weir, 2005).

$$(MD = SEM * 1.96 * \sqrt{2})$$

A Bonferroni's *post hoc* was applied when for instances of a significant F value. The significance level was established a priori as $P \leq 0.05$. Effect sizes (ES) were calculated as post-training mean minus pre-training mean divided by the pooled pre-training standard deviation (Caldwell and Vigotsky, 2020). ES were classified as follows: >0.2 ,

trivial effect; 0.2–0.39, small effect; 0.40–0.79, moderate effect; and ≥ 0.80 , large effect (Cohen, 1992). Descriptive statistics are expressed as the mean $\pm$ standard deviation (SD). All analyses were carried out with SPSS 22.0 (IBM Japan, Inc., Tokyo, Japan).

RESULTS

There were no group differences of either baseline data nor total training volume ($F_{(2,25)} = 1.46$; $P = 0.251$) (Table 2).

****INSERT TABLE 2 NEAR HERE****

There were no group differences for total training volume ($F_{(2,25)} = 1.46$; $P = 0.251$; Fig. 2A) after 8 weeks.

All groups increased their dynamic strength compared to baseline ($F_{(1,24)} = 293.70$; $P = 0.0001$). Analysis revealed a time $\times$ group interaction for the 1-RM barbell back squat (DS = from 142.2 ± 22.2 to 162.8 ± 22.0 kg; RP = from 142.2 ± 22.4 to 168.6 ± 16.3 kg; TRT = from 132.6 ± 20.1 to 149.1 ± 19.7 kg; $F_{(2,24)} = 9.81$; $P = 0.001$; Fig. 2B). Post hoc comparisons revealed that RP promoted higher dynamic muscle strength adaptations compared to TRT ($P = 0.001$) but not to DS ($P = 0.093$); no statistically significant strength differences were observed between DS and TRT ($P = 0.134$). In addition, RP showed a larger effect size (1.18, large) than DS (0.93, large) and TRT (0.81, large).

****INSERT FIGURE 2 NEAR HERE****

All groups similarly increased their muscle thickness at the proximal and middle lateral thigh. There was a significant main effect of time for the proximal (DS = from

45.8 $\pm$ 8.6 to 51.1 $\pm$ 7.6 mm, ES: 0.62; RP = from 48.8 $\pm$ 6.0 to 53.1 $\pm$ 4.8 mm, ES: 0.71; TRT = from 45.9 $\pm$ 8.1 to 52.4 $\pm$ 10.3 mm, ES: 0.80; $F_{(1,24)} = 91.2$, $P = 0.0001$; Fig. 3A) and middle (DS = from 52.0 $\pm$ 3.7 to 56.0 $\pm$ 6.8 mm, ES: 1.06; RP = from 54.8 $\pm$ 3.9 to 57.6 $\pm$ 3.7 mm, ES: 0.72; TRT = from 54.2 $\pm$ 5.8 to 57.7 $\pm$ 6.6 mm, ES: 0.59; $F_{(1,24)} = 68.4$, $P = 0.0001$; Fig. 3B) portions, but not for the distal portion (DS = from 47.7 $\pm$ 2.3 to 48.3 $\pm$ 8.6 mm, ES: 0.24; RP = from 46.7 $\pm$ 4.8 to 50.1 $\pm$ 4.1 mm, ES: 0.70; TRT = from 46.8 $\pm$ 4.8 to 47.2 $\pm$ 6.1 mm, ES: 0.07; $F_{(1,24)} = 0.498$, $P = 0.487$; Fig. 3C (Ho et al. 2019). There were no between-group interactions in any hypertrophy measure (Proximal = $F_{(2,24)} = 0.659$, $P = 0.527$; Middle = $F_{(2,24)} = 0.512$, $P = 0.606$; Distal = $F_{(2,24)} = 0.504$, $P = 0.610$).

**** INSERT FIGURE 3 NEAR HERE ****

There was no difference between groups for intake of either macronutrients (PTN = $F_{(2,25)} = 0.44$; $P = 0.699$; CHO = $F_{(2,25)} = 0.65$; $P = 0.568$; LIP = $F_{(2,25)} = 0.32$; $P = 0.751$) nor energy ($F_{(2,25)} = 0.82$; $P = 0.476$) during the intervention (Table 3).

****INSERT TABLE 3 NEAR HERE****

DISCUSSION

To our knowledge, this is the first study to compare the effects of RP, DS and TRT on muscular adaptations in resistance-trained men. Contrary to our initial hypothesis, findings suggest that RP promotes superior strength increases compared to TRT when total training volume is equalized, but the training systems elicit similar

hypertrophic adaptations. We discuss the specifics of each outcome and their practical implications in the ensuing paragraphs.

All groups increased dynamic strength from pre- to post-study, however RP elicited superior strength adaptations compared to TRT. These findings conflict with previous studies, which reported no differences in strength-related adaptations between RP and TRT in trained males (Korak et al. 2017; Prestes et al. 2019). Consistent with our findings, Angleri et al. (2017) reported that DS elicited similar strength adaptations compared to TRT.

Although a rationale for the observed strength-related superiority of RP versus TRT is not readily apparent, it conceivably may be attributed, at least in part, to the fact that the brief intra-set rest allowed the RP group to train at a higher load for a longer duration in each set than TRT. This would maintain greater mechanical tension on the target muscles, which may have translated into greater strength increases. Whether differences in mechanical tension between conditions were of sufficient magnitude to alter strength changes remains speculative. Further research is warranted to replicate findings and, if confirmed, determine the mechanistic underpinnings.

Muscle thickness increased similarly at all measurement sites along the lateral thigh between training groups. These findings reinforce previous studies that compared hypertrophic responses on resistance training systems. The results refute our research hypothesis that the alternative RT systems would promote superior hypertrophic adaptations compared to TRT with TTV equalized between conditions. Training volume is considered an important variable in the hypertrophic response to RT (Schoenfeld et al., 2017). Although the underlying mechanisms are not well elucidated, it is speculated that a greater amount of mechanical work induces alterations in signaling pathways related to ribosome biogenesis and muscle protein synthesis

(Figueiredo et al. 2018; Hammarström et al. 2020), which ultimately drive increases in muscle mass. Thus, equalizing training volume between conditions is important to determine whether any potential differences are specific to the given system itself. In accordance with our findings, Angleri et al. (2017) and Fink et al. (2018) found similar improvements in cross-sectional area between crescent pyramid, DS and TRT. Alternatively, Prestes et al. (2019) reported greater increases in muscle thickness of the thigh when performing RP versus TRT. Intriguingly, all studies did in fact equate training volume, ruling out potential confounding from this variable.

It is difficult to rationalize discrepancies between our findings and that of Prestes et al. (2019). A possible explanation is that TRT protocol in Prestes et al. (2019) consisted of 3 sets of 6 repetitions performed at 80%1RM, and RP consisted of a single set of repetitions to failure at 80%1RM, with additional short intervals in the same set until participants achieved 18 repetitions. The differences in the repetition range between conditions may have elicited a greater predominance in the glycolytic pathway for the RP group, which in turn may have resulted in greater muscle fiber swelling and metabolic stress, which are theorized to promote anabolism (Schoenfeld, 2013). In contrast, TRT in our study consisted of 4 sets of 12 repetitions at 70% 1RM while RP consisted of 3 sets of 16 repetitions at 75% 1RM; thus, the contribution from the glycolytic energy system seemingly would have been similar between conditions. This hypothesis warrants further study given that glycolytic pathway activity was not measured in both studies and we therefore can only speculate that the observed discrepancies may be partially explained by glycolytic pathway activity.

Intriguingly, MT of the distal thigh portion did not show a significant change from baseline. It is believed that skeletal muscles have specific regions that can receive differing levels of mechanical tension during RT according to biomechanical and

morphological aspects (Zabaleta-Korta et al. 2020). Previous studies indicate that muscle hypertrophy of the quadriceps femoris occur in a non-homogeneous manner, and may be related to region-specific muscle activation and architectural changes (e.g. pennation angle) along the length of the muscle (Ema et al. 2013; Ema et al. 2016; Wells et al. 2014; Wakahara et al. 2017). Accordingly, it is conceivable that mechanical tension may have been greater in the proximal and middle portions than the distal portion, potentially due to joint angle-specific force relationships related to joint range of motion involved in the exercises performed in our experimental protocol. Most of the exercises involved a hip-dominant movement pattern (Escamilla et al. 1998; Lynn and Noffal 2012; Schoenfeld et al. 2015b), which might alter the length-tension curve along the quadriceps femoris and thus induce regional-specific MT responses (Narici et al. 1996; Mangine et al. 2018). It should be noted that although no significant between-group interactions were detected in the distal portion of the quadriceps, the RP method showed higher relative changes in this region with a moderately higher effect size than the other conditions. The practical meaningfulness of these differences remains equivocal and warrants future investigation.

The present study is not without limitations that must be taken into account when attempting to draw practical conclusions. First, our findings are specific to trained males and should not be extrapolated to other populations, such as those new to training, women, and elderly individuals. Second, we employed dynamic strength testing; thus, findings potentially could be different if strength assessments were conducted using isometric or isokinetic tests. Third, we only assessed hypertrophy of a single muscle complex (lateral thigh); thus, results cannot necessarily be generalized to other muscles. Moreover, we did not assess other muscle architectural changes, such as pennation angle and fascicle length, that potentially could have relevance to different training

systems. Although we tried to minimize the possible confounding influence of nutritional intake by employing dietary self-reports, these assessments can display substantial discrepancies between reported versus actual consumption (Mertz et al., 1991). Thus, we cannot rule out the possibility that nutritional differences between conditions may have unduly influenced results. Finally, our findings may have been influenced by changes to the participants' usual and customary RT program. However, post study interviews revealed that the overall volume of our RT protocol was similar to what the participants generally performed for their lower-limbs (~24 to 32 weekly sets, performed once- or twice-weekly). Moreover, the randomization process conceivably should have reduced any confounding issues related to this phenomenon.

In conclusion, our findings indicate that RP may produce superior improvements in strength compared to TRT provided an equalized total training volume. Although no probabilistic statistical differences were observed between groups for MT along the proximal, middle, and distal lateral thigh, effect sizes tended to favor RP versus the other conditions in the distal portion; however, the magnitude of these differences were relatively modest and of questionable practical meaningfulness. It should be noted that RP and DS may be used as a strategy to increase total training volume in a RT session, and thus may have practical relevance beyond the scope of our study design. Further research is warranted to investigate potential benefits for the use of alternative training systems in modulating RT volume.

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CONFLICTS OF INTEREST

The authors declare that they have no conflict of interest.

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Table 1. Training protocols for rest-pause, drop-set and traditional resistance training.

Group	Sets	Reps	Load	Rest Interval
DS	3	10 + 6	75% 1RM 55% 1RM	120s between sets
RP	3	10 + 6	75% 1RM	Intra-set: 20s Between sets: 120s
TRT	4	12	70% 1RM	120s between sets

DS = Drop-set; RP = Rest-pause; TRT = Traditional Resistance Training; RM = repetition maximum; s = seconds.

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Table 2. Baseline data and general characteristics of participants.

Variables	DS (<i>n</i> = 9)	RP (<i>n</i> = 10)	TRT (<i>n</i> = 9)	<i>P</i>
Age (years)	22.4 ± 3.3	24.5 ± 3.8	23.2 ± 2.6	0.41
Height (cm)	178.1 ± 6.3	174.9 ± 6.9	175.6 ± 4.7	0.50
Body mass (kg)	81.6 ± 9.8	80.9 ± 7.7	79.2 ± 5.8	0.79
Body fat (%)	12.1 ± 4.0	15.9 ± 3.2	14.6 ± 3.9	0.11
Experience (years)	5.6 ± 1.5	5.2 ± 2.2	4.4 ± 0.7	0.31
RS Barbell back squat (a.u.)	1.7 ± 0.2	1.7 ± 0.2	1.6 ± 0.2	0.72
1-RM Barbell back squat (kg)	142.2 ± 22.2	142.2 ± 22.4	132.7 ± 20.2	0.91
1-RM 45° Leg press (kg)	372.2 ± 57.4	366.0 ± 48.1	355.3 ± 49.6	0.78
1-RM Seated knee extension (kg)	153.8 ± 21.0	145.5 ± 14.4	151.1 ± 13.6	0.53
1-RM Stiff-leg deadlift (kg)	136.6 ± 10.6	137.2 ± 11.2	128.2 ± 16.1	0.26
1-RM Seated knee flexion (kg)	136.7 ± 19.2	127.5 ± 16.3	128.8 ± 19.0	0.51
Total training volume (kg)	412296.8 ± 50763.9	440363.2 ± 45952.9	405427.5 ± 45747.7	0.25

DS = drop-set; RP = rest-pause; TRT = traditional resistance training; RS = relative strength; AS = absolute strength; A.U = arbitrary units; cm = centimeters; kg = kilograms.

Table 3. Total energy and macronutrients intake every four weeks.

Groups	Variables	Week 1	Week 4	Week 8
Drop-Set (n = 9)	Total (kcal)	2874.1 ± 1024.1	2989.6 ± 973.4	2851.4 ± 766.7
	PTN (g)	207.3 ± 52.8	209.8 ± 59.3	211.5 ± 47.6
	CHO (g)	334.1 ± 162.9	342.8 ± 174.8	326.3 ± 139.6
	LIP (g)	76.5 ± 39.0	85.0 ± 26.0	77.9 ± 26.0
Rest-Pause (n = 10)	Total (kcal)	2658.7 ± 876.6	2412.4 ± 901.0	2515.9 ± 919.4
	PTN (g)	180.6 ± 60.2	173.1 ± 51.3	171.5 ± 51.6
	CHO (g)	289.4 ± 130.1	251.8 ± 113.1	268.9 ± 116.8
	LIP (g)	81.0 ± 39.8	78.3 ± 44.6	83.5 ± 44.2
Traditional (n = 9)	Total (kcal)	2901.4 ± 813.2	2600.3 ± 583.5	2487.7 ± 515.0
	PTN (g)	180.7 ± 75.6	166.5 ± 76.2	161.2 ± 73.8
	CHO (g)	336.9 ± 142.2	284.8 ± 55.5	270.2 ± 54.2
	LIP (g)	80.6 ± 20.3	90.1 ± 31.6	86.1 ± 31.1

g = grams; KCAL = kilocalories; PTN = protein; CHO = carbohydrate; LIP = lipids.

FIGURE LEGENDS

Figure 1. Thigh portions and an ultrasound image of middle portion. F = Femur; VI = Vastus Intermedius; VL = Vastus Lateralis.

Figure 2. Estimation plot of the paired mean difference for 1RM changes in the back squat for within-subjects (top) and between-groups (bottom) conditions. The raw data are plotted on the upper axes; each paired set of observations is connected by a line. On the lower axes, each paired mean difference is plotted as a bootstrap sampling distribution. Mean differences are depicted as dots; 95% confidence intervals are indicated by the ends of the vertical error bars. DS = drop-set; RP = rest-pause; TRT = traditional resistance training.

Figure 3. Estimation plot of the paired mean difference for hypertrophic responses for proximal (30% - A), middle (50% - B) and distal (70% - C) portions of lateral thigh for within-subjects (top) and between-groups (bottom) conditions. The raw data are plotted on the upper axes; each paired set of observations is connected by a line. On the lower axes, each paired mean difference is plotted as a bootstrap sampling distribution. Mean differences are depicted as dots; 95% confidence intervals are indicated by the ends of the vertical error bars. DS = drop-set; RP = rest-pause; TRT = traditional resistance training.

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