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ORIGINAL ARTICLE

Comparison of changes in lean body mass with a strength-versus muscle endurance-based resistance training program

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Abstract

Purpose The aim of this study was to compare the effects of resistance training (RT) with an emphasis on either muscular strength-type RT or muscular endurance-type RT on measures of body composition.

Methods Twenty-five resistance-trained men (age 28.4 ± 6.4 years; body mass 75.9 ± 8.4 kg; height 176.9 ± 7.5 cm) were randomly assigned to either a strength-type RT group that performed three sets of 6–8 repetition maximum (RM) with 3-min rest ($n = 10$), an endurance-type RT group that performed three sets of 20–25 RM with a 60-s rest interval ($n = 10$), or a control group ($n = 5$, CG). All groups completed each set until muscular failure and were supervised to follow a hyperenergetic diet (39 kcal·kg^{-1}·day^{-1}). Body composition changes were measured by dual-energy X-ray absorptiometry.

Results After 8 weeks, we found significant increases in total body mass (0.9 [0.3–1.5] kg; $p < 0.05$; ES = < 0.2) and lean body mass (LBM) (1.3 [0.5–2.2] kg; $p < 0.05$; ES = 0.31) only in the strength-type RT group; however, no significant interactions were noted between groups.

Conclusions Although only strength-type RT showed statistically significant increases in LBM from baseline, no between-group differences were noted for any body composition outcome. These findings suggest that LBM gains in resistance trained are not significantly influenced by the type of training stimulus over an 8-week training period.

Keywords Body composition · Exercise · Physiology · Fitness · Training

Abbreviations

RT	Resistance training
LBM	Lean body mass
CG	Control group
BM	Body mass
DXA	Dual-energy X-ray absorptiometry
SD	Standard deviation
GLM	General linear model
FM	Fat mass
RM	Repetition maximum
MRI	Magnetic resonance imaging

Introduction

Current theory postulates that the manipulation of program variables is necessary to maximize resistance training-induced muscular adaptations (ACSM 2009). Several mechanisms have been proposed to elicit muscle hypertrophy, including mechanical tension and metabolic stress. It is believed that these training-related factors promote

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adaptations by different signaling cascades that can be targeted by altering program variables (Schoenfeld 2010).

To infer causality, most research studies compare program variables in an isolated manner, with all other variables equated. In this regard, numerous authors have investigated the effects of manipulating variables on body composition. For instance, rest interval periods between sets (Gentil et al. 2010; Villanueva et al. 2015), time under tension (Shepstone et al. 2005; Usui et al. 2016), number of repetitions adjusted for the corresponding load/intensity (Kushner et al. 2015; Morton et al. 2016), volume (Radaelli et al. 2015), frequency (Schoenfeld et al. 2015b), selection and order of exercises (Assumpcao et al. 2013; Dias et al. 2010), and repetitions until volitional failure (Sampson and Groeller 2016) all have been investigated. These studies have been carried out in a variety of populations, generally employing sedentary subjects or those with less than 6 months of resistance training (RT). Manipulating variables separately might favor the production of either mechanical tension or metabolic stress in one group more than the other. In general, strength-type RT employing heavier loads and longer rest intervals favor higher mechanical tension, whereas endurance-type RT with lighter loads and shorter rest intervals promote a greater accumulation of metabolites (Schoenfeld 2010). Research indicates that a longer time under tension during a set increases the accumulation of metabolites (Rogatzki et al. 2014). Accordingly, working muscle groups in an alternating fashion (i.e., upper limbs and lower limbs, push and pull exercises, etc.) has been proposed as a training strategy that allows the recovery of one muscle group while working another (Baechle et al. 2008; Sheppard and Haff 2016).

Previously, Schoenfeld et al. (2014) found no differences in elbow flexor hypertrophy between a "bodybuilding-type" protocol whereby resistance-trained men performed three sets of 10RM with a 1-min rest interval versus a "powerlifting-type" protocol whereby subjects performed seven sets of 3RM with a 3-min rest interval. Alternatively, Mangine et al. (Mangine et al. 2015) reported greater increases in lean arm mass when resistance-trained men performed three sets of 90% 1RM with a 3-min rest interval versus three sets of 70% 1RM with 1-min rest between sets. However, neither of these studies endeavored to manipulate the spectrum of RT variables to maximize mechanical tension versus metabolic stress.

The purpose of this randomized controlled study was to evaluate the effects of two different RT protocols by manipulating training variables with either a strength- or endurance-type focus on markers of hypertrophy in trained men. Under a supervised hyperenergetic diet, we manipulated multiple variables including load, number of repetitions, rest interval between sets, exercise order, and the cadence of concentric and eccentric actions in an effort to maximize mechanical or metabolic stressors. Based on previous meta-analysis data, we hypothesized that both training protocols would equally enhance gains in lean body mass (LBM) when combined with a supervised hyperenergetic diet (Schoenfeld et al. 2017).

Methods

Subjects

Twenty-five subjects with more than 2 years of continuous experience in RT (mean training age = 7.96 ± 4.15 years) volunteered to participate in this study (age = 28.4 ± 6.4 years; body mass = 75.9 ± 8.4 kg; height = 176.9 ± 7.5 cm; BMI = 24.4 ± 2.1 kg/m^2). All individuals committed to adhere to the prescribed training and dietary protocols during the 8 weeks of the study, with no exercise performed or food consumed other than those proposed. Two subjects who admitted to having used androgenic–anabolic steroids during the last 2 years or consumed any type of dietary supplement were excluded from the study. The subjects were informed of the possible risks of the experiment and signed a consent form. The research protocol was reviewed and approved by the Ethics Committee of the EADE-University of Wales Trinity Saint David (Wales, United Kingdom). The study was developed following the ethical guidelines of the Declaration of Helsinki (WMA 2013) (Table 1).

Study design

The participants were randomly assigned to perform RT with either a muscular strength-type RT focus ($n = 10$), a muscular endurance-type RT focus ($n = 10$) or a control group that followed their usual and customary fitness program (CG) ($n = 5$). Both groups performed four training sessions per week organized as a split routine, with 2 days allocated for the upper limbs and 2 days allocated for the lower limbs, and 72 h of rest afforded between

Table 1 Characteristics of participants at baseline

	Strength	Endurance	Control	p
Age (years)	27.1 ± 5.6	28.0 ± 7.7	31.6 ± 4.6	0.440
Height (cm)	178.3 ± 6.2	174.1 ± 8.3	179.9 ± 7.8	0.285
BM (kg)	74.6 ± 5.3	75.7 ± 11.7	78.9 ± 6.5	0.656
BMI (kg m^2)	23.9 ± 1.6	24.9 ± 2.4	24.5 ± 1.7	0.477
Experience (years)	7.13 ± 3.41	6.77 ± 3.19	11.76 ± 5.45	0.062
FM (kg)	11.3 ± 2.6	12.4 ± 4.9	13.4 ± 4.5	0.641
LBM (kg)	63.2 ± 4.4	63.3 ± 8.1	65.6 ± 2.6	0.744

Data are means ± SD

BM body mass, *BMI* body mass index, *FM* fat mass, *LBM* lean body mass, $p < 0.05$ is considered significant sessions for the same muscles. The training program lasted 8 weeks. All sets in the experimental groups were performed to volitional failure.

Procedures

Training protocols

All routines were directly supervised by the research team, which included certified personal trainers to ensure proper performance of the respective routines based on National Strength and Conditioning Association protocols. All subjects were familiar with the exercises and standardized diets.

The manipulation of exercise variables was designed to elicit greater mechanical tension in the strength-type RT group and greater metabolic stress in the endurance-type RT group. Specifically, strength-type RT performed exercises in an alternating push and pull fashion as follows: (i) upper limbs: bench press, pull-ups, dumbbell lateral raise, incline press, barbell row, military press, biceps curl and triceps dip; and (ii) lower limbs: squat, deadlift, leg press, lying leg curl, leg extension, hip thrust, standing calf raise and calf raise press. Alternatively, exercises for the endurance-type RT group were structured so that each muscle group was trained in series as follows: (i) upper limbs: bench press, incline press, military press, triceps dip, pull-ups, barbell row, biceps curl and dumbbell lateral raise; and (ii) lower limbs: squat, leg press, leg extension, deadlift, lying leg curl, hip thrust, standing calf raise, and calf raise press. The control group was instructed to continue with their usual and customary training program during the entire duration of the experiment; no specific intervention was prescribed but strength levels and body composition were evaluated pre-and post-study.

Progression of load was employed for both experimental groups, whereby the magnitude of load was increased whenever a subject exceeded the target repetition range while using proper technique. In doing so, the lifted loads and perceived exertion in each exercise were monitored by the physical conditioning and strength specialist using a paper tracking form throughout the experiment. Table 2 details the specific manipulation of variables for both the strength-type RT and endurance-type RT protocols.

Dietary intake

A sports nutrition specialist prescribed individualized dietary regimens for each participant. A protein intake of 2 $g \cdot kg^{-1} \cdot day^{-1}$ was prescribed, as this amount is in the upper range shown to maximize lean tissue accretion (Aragon et al. 2017; Jager et al. 2017). Regarding other macronutrients, a caloric intake of 25% was established from fats, and the balance of the diet was obtained from carbohydrates (until completing the total caloric requirement of 39 $kcal \cdot kg^{-1} \cdot day^{-1}$). Diet structure and monitoring, in terms of distribution and frequency, were supervised by a sports nutrition specialist to ensure adherence to total daily caloric values and macronutrient distribution, given these factors are important to determine RT-induced muscular adaptations (Helms et al. 2014). Food records were entered into a MyFitnessPal app (MyFitnessPal, LLC, CA, USA), which has been validated as viable tool for energy assessment (Teixeira et al. 2018). Similar foods were recommended for the diets of all subjects in strength-type RT and endurance-type RT group, while subjects in the control group maintained their habitual feeding (they were not asked to follow a specific diet).

Body composition

Body mass (BM) and regional body composition were assessed using a Hologic QDR 4500 dual-energy X-ray absorptiometry (DXA) scanner (Hologic Inc., Bedford, MA, USA). Each subject was scanned by a certified technician, and the distinguished bone and soft tissue, edge detection, and regional demarcations were assessed by computer algorithms with APEX Software 3.0 (APEX Corporation Software, Pittsburg, PA, USA). For each scan, subjects wore sport clothes and were asked to remove all materials that could attenuate the X-ray beam, including jewelry items. Calibration of the densitometer was checked daily against a standard calibration block supplied by the manufacturer.

Statistical analysis

Descriptive statistics tests were reported as the mean and standard deviation (*SD*). Data were analyzed using a univariate, multivariate and repeated measures general linear model (GLM), with two levels of time (pre- and post-test) and using groups (strength-type RT, endurance-type RT and

Table 2 Training protocols for the study groups (strength and endurance)

Group	Sets	Reps	Rest	Time	Muscle failure	TUT	Total sets
Strength	3	6–8 RM	3 min	30X[a]	Yes	18–24 s	24
Endurance	3	20–25 RM	1 min	201	Yes	60–75 s	24

TUT time under tension, *RM* repetition maximum

[a] X denotes high-velocity explosive concentric action

CG) as an inter-subject factor. Wilks' Lambda multivariate tests were reported to describe overall effects of related variables analyzed. Greenhouse–Geisser univariate tests with least significant difference and post hoc comparisons (Bonferroni correction) were presented for individual variables analyzed. Partial eta-squared effect sizes (ηp^2) were also reported on select variables as an indicator of effect size (ES) of the repeated measures GLM. An eta squared of 0.02 was considered small, 0.13 medium, and 0.26 large (Dalton et al. 2017). A one-way analysis of variance (ANOVA), with a 95% confidence level and Bonferroni post hoc correction was performed to detect between-group differences in the Δ changes (post-test—pre-test), as is recommended for these studies (Nakagawa and Cuthill 2007). In addition, ES calculation was done with Cohen's *d*, as a standardized measurement based on SD differences; while $d = 0.2$ was considered a small effect, $d = 0.5$ was a medium effect and $d = 0.8$ was a large effect, which is used as a guide for substantive significance. The normal Gaussian distribution of the data was verified by the Shapiro–Wilk test. These statistical analyses were performed with licensed Statistical Package for the Social Sciences (SPSS) software (SPSS 24.0, IBM Corp., Armonk, NY, USA), GraphPad Prism software version 7.03 (GraphPad software, California, USA), and Estimation Statistics Beta program (see http://www.estimationstats.com).

Results

The statistical results before and after the intervention for total BM, fat mass (FM), and LBM in strength-type RT, endurance-type RT and CG are shown in Table 3.

Analysis of the GLM of repeated measures showed no significant differences ($p > 0.05$) for BW considering the effects of the factors (Time, Group or Time × Group). Regarding Δ by group, the endurance-type RT group showed a non-significant slight decrease in BM (− 0.8 [− 2.9 to 1.2] kg, $p > 0.05$, ES = − 0.08). The strength-type RT group showed a statistically significant increase in BM after the intervention (0.9 [0.3–1.5] kg, $p < 0.05$), although the effect was trivial (ES < 0.2). The CG did not show a significant change in BM (0.3 [− 1.2 to 1.9] kg, $p > 0.05$, ES = 0.18). In accordance with the group comparison test, no difference was found in the change Δ in BM. Figure 1 provides a graphical illustration of both mean and individual changes in body composition.

A significant difference was found in FM ($p = 0.04$, $\eta p^2 = 0.17$) between the means (Time) according to the univariate model; no difference was found between the means when the model included the Group or Group x Time interaction. Regarding Δ by group, a slight but not statistically significant decrease was shown for the strength-type RT group (− 0.5 [− 1.2 to 0.3] kg, $p > 0.05$, ES ≤ 0.2), endurance-type RT group (− 0.9) [− 2.0 to 0.3] kg, $p > 0.05$, ES = 0.46) and control group (− 0.5 [− 2.4 to 1.3] kg, $p > 0.05$, ES ≤ 0.2). No significant differences were seen in the comparison of Δ for FM between groups ($p > 0.05$) (Fig. 1).

Regarding LBM, the univariate analysis showed a difference between the mean (Time) ($p = 0.01$, $\eta p^2 = 0.25$), but not for comparisons by Group or Time × Group ($p > 0.05$). The results for each group (considering the Δ) showed a significant increase in the strength-type RT group (1.3 [0.5–2.2] kg, $p < 0.05$), but with a small effect size (ES = 0.31). However, no significant changes were displayed in the endurance-type RT group (0.03 [− 1.1 to 1.1] kg); $p > 0.05$; ES < 0.2 or in the CG (0.8 [− 0.4 to 2.1] kg; $p > 0.05$; ES = 0.26) (Fig. 1). ANOVA for the comparison of Δ for the LBM determined that there was no significant difference between groups ($p > 0.05$).

Table 3 Results before and after the intervention for body composition by groups

	Group	Before	After	Cohen's d (ES)	Interaction	*p* value (ηp^2)
BM (kg)	Strength	74.6 ± 5.3	75.5 ± 4.9^a	0.18	Time	0.78 (0.003)
	Endurance	75.7 ± 11.7	74.9 ± 10.4	− 0.08	Group	0.63 (0.04)
	Control	78.9 ± 6.5	79.2 ± 6.6	0.05	Time × group	0.17 (0.15)
FM (kg)	Strength	11.3 ± 2.6	10.9 ± 2.7	− 0.12	Time	0.04 (0.17)
	Endurance	12.4 ± 4.9	11.6 ± 4.2	− 0.46	Group	0.63 (0.04)
	Control	13.4 ± 4.5	12.8 ± 4.0	− 0.12	Time × group	0.77 (0.02)
LBM (kg)	Strength	63.2 ± 4.4	64.6 ± 4.2^a	0.31	Time	0.01 (0.25)
	Endurance	63.3 ± 8.1	63.3 ± 7.5	0.004	Group	0.69 (0.03)
	Control	65.6 ± 2.6	66.4 ± 3.5	0.26	Time × group	0.10 (0.19)

Data are means ± SD. Multivariate analysis revealed overall Wilks' Lambda time ($p = 0.003$; $\eta p^2 = 0.490$), Time × Group ($p = 0.230$; $\eta p^2 = 0.176$). Greenhouse–Geisser univariate *p*-levels are presented for each variable. $p < 0.05$ is considered significant

ES effect size, *BM* body mass, *FM* fat mass, *LBM* lean body mass

[a] Denotes a significant difference from baseline

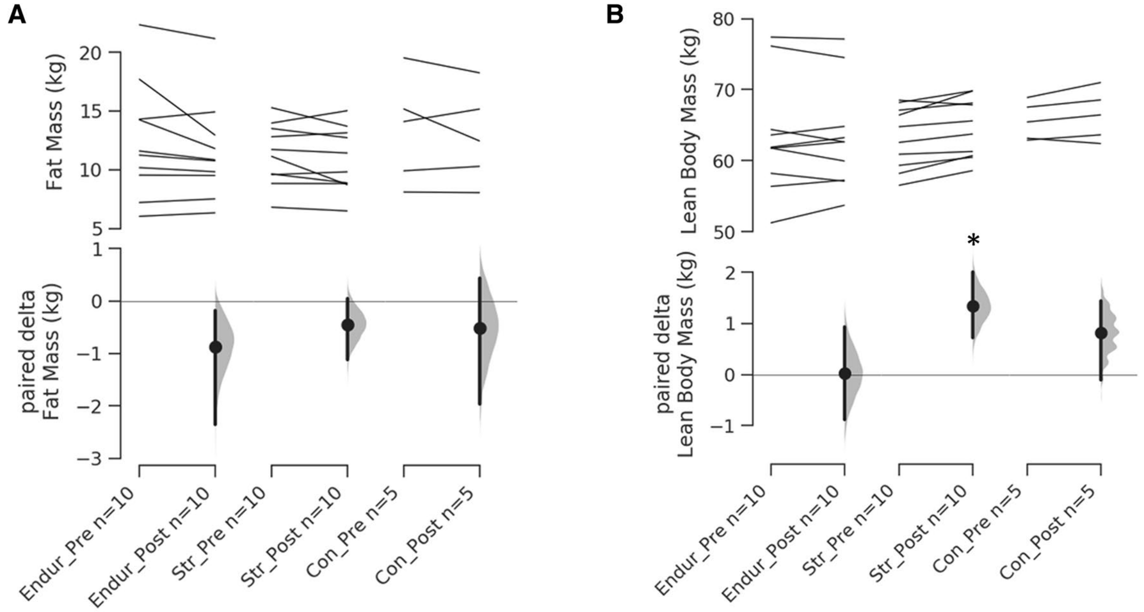

Fig. 1 **a** Changes in fat mass; **b** Changes in lean body mass. Mean changes with 95% confidence intervals completely above or below the baseline are significant changes. *Denotes a significant difference from baseline

The strength-type RT group showed an increase in BW attributed exclusively to the increase in LBM, as there was a slight decrease in FM. Neither of the two experimental protocols promoted a statistically significant decrease in adiposity.

Discussion

The present study evaluated the effects of two RT protocols on muscle mass in resistance-trained subjects, manipulating several program variables to focus on routines with an emphasis on either strength-type RT (high mechanical stress) or endurance-type RT (high metabolic stress). Our results demonstrated that RT carried out with a strength-related focus had greater absolute effects on estimates of LBM in comparison with a muscular endurance-related focus. However, the results did not rise to the level of statistical significance between groups, and the size of effect was of a small magnitude, calling into question the practical relevance of these findings.

Several previous studies have endeavored to explore the present topic, and the results have been inconsistent. For instance, Chestnut and Docherty (1999) compared volume-equated training protocols with heavy loads (four repetitions) and longer rest intervals (3 min) that emphasized strength-type RT, versus moderate loads (ten repetitions) and shorter rest intervals (2 min) that emphasized endurance-type RT in a cohort of untrained young men; both conditions significantly increased muscle cross-sectional area, specific tension, and flexed and tensed arm girth to a similar extent (Chestnut and Docherty 1999). Alternatively, Campos et al. (Campos et al. 2002) randomized untrained subjects to one of three training protocols: a group that performed four sets of 3–5 RM (low repetitions) with 3 min of rest; three sets of 9–11 RM (intermediate repetitions) with 2 min of rest; or two sets of 20–28 RM (high repetitions) with 1 min of rest. Results showed that RT with low and intermediate repetitions induced a significant hypertrophy across the spectrum of muscle fibers (I, IIA and IIX), but no significant changes were seen in the group that trained with high repetitions. In contrast (Schoenfeld et al. 2014), randomized resistance-trained men to either a bodybuilder-type training protocol (three sets of 10 RM with 90-s rest intervals) versus a powerlifting-type protocol (seven sets of 3 RM with 3-min rest intervals). After an 8-week study period, both protocols promoted similar increases in muscle size. In opposition to previous findings, Fink et al. randomized young gymnasts to an 8-week protocol involving either medium/high loads (8 RM) with 3 min of rest, or light loads (20 RM) with 30 s of rest (Fink et al. 2018). Although both conditions induced a hypertrophic response, RT focused on muscular endurance promoted greater increases in muscle cross-sectional area compared to the strength-related protocol (9.9% vs 4.7%, respectively). Differences between our study and previous work may be attributed to the fact that we endeavored to manipulate as many variables as possible including repetition zone, rest interval, order of exercises and cadence in an effort to maximize either mechanical tension (in the strength-type RT group) or metabolic stress (in the endurance-type RT group). Our results showing a greater accretion of LBM for the strength-type RT condition may be explained by the recent acute findings of Haun et al. (2017), who demonstrated that training with light loads (e.g., 30% 1RM) impairs recovery compared with heavy loads (e.g., 80% 1RM). Moreover, (Schoenfeld et al. 2016b) found that short rest intervals (60 s), which are associated with a higher metabolite buildup (Henselmans and Schoenfeld 2014), blunted the hypertrophic response compared to longer rest intervals (3 min), possibly resulting from a reduction in total training volume. This raises the possibility that the shorter rest periods employed in the endurance-type RT group may have somewhat negatively impacted muscular development, nullifying any potential anabolic effects of higher metabolite accumulation.

Regarding subjects with experience in RT, previous work found that training with low loads (25–35 repetitions) and medium loads (8–12 repetitions) to muscle failure similarly increased muscle hypertrophy; although it should be noted that training with medium loads produced superior gains in muscle strength (Schoenfeld et al. 2015a). These results are somewhat consistent with ours in regard to muscle growth, as we found no statistically significant differences between protocols. However, on an absolute basis, only the strength-type RT significantly increased LBM from baseline, albeit the corresponding between-group effect size difference was small. It is possible that discrepancies between the two studies may be explained, at least in part, by the different measurement tools employed: Schoenfeld et al. (2015a) measured site-specific muscle thickness of the limbs using B-mode ultrasound, whereas we evaluated whole body LBM through DXA.

It is worth noting that there was a large interindividual response within protocols, as is the case with most training studies (Hubal et al. 2005). For instance, although results for the endurance-type RT group did not reach statistical significance, some subjects showed substantial increases in lean mass (e.g., $\Delta = 4.6\%$) while others failed to make gains (e.g., $\Delta = -3.0\%$) (see Fig. 1). Similarly, the results for changes in fat mass were disparate across groups, with some accreting body fat and others showing losses. This indicates that, with the same RT programming and standardized diet, differential responses are obtained that may be due to the individual conditions of each subject (i.e. genetic and environmental factors). The well-trained status of the subjects may have contributed to these variances, given that it becomes increasingly difficult to add appreciable muscle mass as one gains considerable RT experience. Therefore, these considerations must be taken into account in program design, highlighting the importance of systematic trial and error in determining the optimal program prescription for a given individual. Given the relatively small sample in this study, further work is needed with larger samples to fully evaluate the effects of endurance-type RT and strength-type RT on muscle hypertrophy in responders and non-responders.

This study had a number of strengths, including direct supervision of all training sessions and a tightly controlled nutritional protocol that is absent in previous studies on the topic. That said, there are several limitations that should be taken into account when attempting to draw practical inferences. First, the duration was fairly short (8 weeks). It is known that with RT, the strength and hypertrophy gains tend to decrease over time (Schiotz et al. 1998). Thus, it cannot necessarily be extrapolated that the results observed in the strength-type RT group would continue over a longer timeframe. Second, a larger number of participants may be needed for further analysis of responders versus non-responders, especially with regard to body composition measurements. Third, there was an absence of physiological markers to compare the acute effects of both training protocols. Measurements of these markers (e.g., MGF, IGF, etc.) might be necessary to assess hormonal responses in further detail. Finally, although DXA is a valid method for assessing body composition, it may not be sensitive enough to detect subtle changes in muscle mass over time (Levine et al. 2000); future studies on the topic should endeavor to employ site-specific evaluations of hypertrophy such as MRI and ultrasound.

Conclusions

Our results indicate that performing RT training with a strength-related focus elicits similar changes in body composition compared to a program focused on muscular endurance in resistance-trained men under controlled dietary conditions. While the strength-related protocol showed greater absolute increases in LBM, the relatively small magnitude of effect raises circumspection as to the practical meaningfulness of benefits. It is possible that combining heavy and light load protocols to promote both high levels of mechanical tension and high levels of metabolic stress may be synergistic to the hypertrophic response (Schoenfeld et al. 2016a). Future research should seek to fill in the gap in the current literature.

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Author contributions SV served as study manager. SV conceived and designed the experiments. RR and JBP served as lab coordinator and project manager for study coordination, respectively. SV and RR assisted in data collection. SV and MF designed the nutritional protocols. SV oversaw nutrition and training. JLP analyzed the data. SV, BJS, JLP, RK, JBP, RR and DAB assisted in analysis and manuscript review. SV, JLP, and BJS wrote the paper. JBP, JLP, DAB, BJS, and RK assisted in the statistics advice, discussion analysis, and manuscript preparation. All authors read and approved the final manuscript.

Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

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