Effects of Different Weekly Sets-Equated Resistance Training Frequencies on Muscular Strength, Muscle Mass, and Body Fat in Older Women

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Abstract

Pina, FLC, Nunes, JP, Schoenfeld, BJ, Nascimento, MA, Gerage, AM, Januário, RSB, Carneiro, NH, Cyrino, ES, and Oliveira, AR. Effects of different weekly sets-equated resistance training frequencies on muscular strength, muscle mass and body fat in older women. *J Strength Cond Res* XX(X): 000–000, 2019—The aim of this study was to analyze the effects of different resistance training (RT) frequencies (2 vs. 3 times per week) with an equivalent number of weekly sets performed between conditions on muscular strength and body composition in older women. Forty-seven older women (65 ± 4 years) were divided into 2 groups that performed a 12-week RT program either 2 (G2x and 3 sets) or 3 (G3x and 2 sets) times per week. The groups were evaluated before and after study on measures of body composition through dual-energy x-ray absorptiometry, and muscular strength through one repetition maximum (1RM) testing. Lean soft tissue was significantly increased in both groups (G2x = +1.7%, G3x = +1.7%), while only G3x reduced body fat after the intervention period (G2x = −0.7%, G3x = −2.9%). Similarly, significant increases were noted between conditions for 1RM scores in bench press (G2x = +11.8%, G3x = +11.9%) and knee extension (G2x = +17.4%, G3x = +10.8%). The results indicate that performing 2 or 3 RT sessions per week promotes similar improvements in muscular outcomes, while training more frequently may reduce body fat after 12 weeks of weekly sets-equated RT in untrained older women.

Key Words: hypertrophy, volume, strength training, weight training, aging, elderly

Introduction

Aging is associated with a variety of negative physical complications including alterations in body composition and reductions in muscle strength (6,30). These age-induced changes impair physical fitness, which in turn limits the capacity to perform daily living activities and exercise. This ultimately leads to a cyclical process that encompasses sarcopenia, frailty, and increased sedentary behavior (6,13). Resistance training (RT) has been widely recommended as a means to counteract these age-related issues because of its effects on enhancing physical capacity as well as increasing active life expectancy (10) and health in older adults (30,31).

Primary beneficial effects of RT include improvements in strength and body composition (1,2). Optimal RT-induced adaptations are dependent on proper manipulation of the training variables (4), which include intensity (e.g., external load used during the exercises) (24), level of effort (e.g., training near or to failure) (16), and volume (e.g., the number of sessions, sets, and repetitions performed) (17,23,25). In relation to training frequency, it is considered as the number of sessions performed over a specified period, usually a week (17,23). Current evidence indicates that higher intensities are required for greater 1 repetition maximum (RM) strength gains (8,19,24), while higher volumes are desired for greater gains in muscle mass (22,25). In this way, increasing weekly RT frequency may be indicated for obtaining greater muscular adaptations, but only as a means to increase total weekly training volume (17,23).

In this sense, recent systematic reviews and meta-analyses on the topic (17,23) suggest that it is necessary to equate the total volume, often expressed in terms of weekly number of sets (3,25), to determine causality as to verify the actual influence of weekly frequency of RT on muscular adaptations; otherwise, the effects of volume confound the ability to draw proper inferences on the topic. When volume is controlled between conditions, RT protocols using different frequencies have been found to produce similar muscular adaptations, at least in young individuals (17,23). However, some researchers have hypothesized that training more frequently may confer an advantage, even when comparing volume-matched protocols (11). This is based on the supposition that performing less-frequent RT sessions with greater intrasession volume exceeds the body's capacity to increase the postexercise muscle protein synthesis (MPS) response, thereby resulting in "wasted sets." Thus, fractionating weekly volume (i.e., more frequently) may provide a more economical distribution of sets, so that the area-under-the-curve MPS response is maximized throughout the week (11).

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General training guidelines for older adults recommend performing RT 2 to 3 times per week (1). Studies comparing the effects of RT frequencies on muscular adaptations are conflicting, whereby some studies show similarity between protocols (21,27), while others indicate some superiority for higher frequencies (14,29). However, to the best of our knowledge, no study to date has compared different RT frequencies in an older population under volume-matched conditions. It is feasible that muscular adaptations pursuant to different RT frequencies may diverge between younger and older individuals, given that aging is associated with an altered MPS response (12). In regard to body fat, there is limited evidence that higher frequencies help to accelerate fat loss in middle-aged individuals when volumes are not equated (26); however, once again, no study has endeavored to compare protocols on a volume-matched basis in an elderly population. Therefore, the aim of the current study was to compare the effects of different RT frequencies on muscular strength and body composition in older women, with the number of weekly sets equated between conditions. It was hypothesized that the both RT frequencies would show similar improvements in analyzed outcomes.

Methods

Experimental Approach to the Problem

The total duration of the study lasted 16 weeks, in which the first 2 weeks (weeks 1–2) were used for familiarization with the RT program exercises, and pre-training measures, and the last 2 weeks (weeks 15–16) were dedicated to post-training measures. The intervention period lasted 12 weeks (weeks 3–14). Subjects were assessed at preintervention and postintervention for measures of muscular strength, anthropometry, and body composition.

Subjects

Recruitment was performed through newspaper and radio advertisements, and home delivery of flyers in the central city area and residential neighborhoods. Interested subjects completed detailed health history and physical activity questionnaires and were subsequently admitted to the study if they met the following inclusion criteria: female, ≥60 years old, physically independent, had no orthopedic conditions that would prevent them from performing the prescribed exercise or exercise testing associated with the study and were not receiving hormonal replacement therapy. Three hundred and fifty elderly women volunteered for the project and underwent personal interviews at the laboratory, where the intervention was explained in detail. Subsequently, 47 physically independent women who met all inclusion criteria and returned to the laboratory for initial analysis were evaluated by a cardiologist (resting 12-lead electrocardiogram test, personal interview, and treadmill stress test when deemed necessary) and released with no contraindications to exercise. Subjects were randomly assigned to 1 of the 2 groups: a group that performed RT 2 times per week (G2x, 3 sets, $n = 23$; 65.4 ± 4.4 years; 62.5 ± 7.8 kg; 156.2 ± 5.9 cm; 25.7 ± 3.3 $kg \cdot m^{-2}$) or a group that performed RT 3 times per week (G3x, 2 sets, $n = 24$; 64.9 ± 4.6 years; 61.0 ± 8.8 kg; 156.3 ± 5.8 cm; 24.9 ± 3.2 $kg \cdot m^{-2}$). Written informed consent was obtained from all subjects. All testing and training procedures were conducted according to the Declaration of Helsinki and approved by the Londrina State University Ethics Committee (Project 04743, number 21750/2006).

Procedures

Muscular Strength. Maximal dynamic strength was evaluated using 1RM tests assessed on the chest press and knee extension exercises. Testing for each exercise was preceded by a warm-up set (6–10 repetitions) with approximately 50% of the estimated load used in the first attempt of the 1RM. This warm-up was also used to familiarize the subjects with the testing equipment and lifting technique. The testing procedure was initiated 2 minutes after warm-up. During the 1RM tests, the subjects were encouraged to attempt to accomplish 2 repetitions with the imposed load and given 3 attempts to reach a 1RM in all exercises. The rest period was 3–5 minutes between each attempt and 5 minutes between exercises. Technique for each exercise was standardized and continuously monitored to ensure reliability. All 1RM testing sessions were supervised by 2 experienced researchers to help ensure safety and integrity. Verbal encouragement was provided throughout each test. Three 1RM test sessions were performed separated by 48 hours (chest press: standard error of estimation [*SEE*] = 0.46 kg and intraclass correlation coefficient [ICC] >0.97; knee extension: *SEE* = 1.67 kg and ICC >0.91), and the 1RM was recorded as the heaviest load lifted in which the subject was able to complete only one maximal execution among the 3 sessions.

Body Composition. Whole-body dual-energy x-ray absorptiometry scans (Lunar Prodigy, model NRL 41990; General Electric Lunar, Madison, WI, USA) were used to determine lean soft tissue and fat mass. To minimize possible estimation errors, subjects were instructed to urinate ~30 minutes before the measurements, to abstain from eating or drinking in the previous 4 hours, to avoid vigorous physical exercise for at least 24 hours, and to abstain from alcoholic and caffeinated beverages for at least 48 hours. Before scanning, subjects were instructed to remove all objects containing metal. Scans were performed with the subjects lying supine along the table's longitudinal centerline axis. Feet were taped together at the toes to immobilize the legs, and the hands were maintained in a pronated position within the scanning region. Both calibration and analysis were performed by a skilled laboratory technician, following the manufacturer's recommendations. The software generated standard lines that segmented the limbs from the trunk and head. The same technician adjusted the lines using specific anatomical points determined by the manufacturer and performed analyses during the intervention. Previous measurements (test-retest) were obtained in 9 subjects with a 24-hour interval between them, which resulted in an *SEE* of 0.29 and 0.90 kg, and ICC of 0.99 and 0.98 for lean soft tissue and fat mass, respectively.

Resistance Training Program. Resistance training was performed during the morning hours in the University fitness facility. The protocol was based on recommendations for RT in an older population to improve muscle strength and hypertrophy (1,2). All subjects were personally supervised by physical education professionals with substantial RT experience to ensure consistent and safe exercise performance. Subjects performed RT using a combination of free weights and machines (Bad Boy Gym, São Paulo-SP, Brazil). The sessions were performed in the morning on Tuesday and Thursday for the G2x, and on Mondays, Wednesdays, and Fridays for the G3x. The RT program worked the entire body with 8 exercises comprising one exercise with free weights and 7 with machines performed in the following order: vertical chest press, knee extension, lat pulldown, leg curl, preacher Scott curl, seated calf raise, triceps pushdown, and abdominal trunk flexion. Each set was performed with 10–15RM, with the exception of the seated calf raise (15–20 RM) and abdominal trunk flexion (20–30 repetitions, without additional external load). For G2x, each exercise was performed with 3 sets, while for G3x 2 sets were performed per exercise. Rest between sets and exercises were 1–2 and 2–3 minutes, respectively. Subjects were instructed to inhale during the eccentric phase and exhale during the concentric phase while maintaining a constant velocity of movement at a ratio of approximately 1:2 (concentric and eccentric phases, respectively). Load was progressively increased each week from 2 to 5% for upper-limb exercises and 5–10% for lower-limb exercises where applicable, as recommended in the literature (1).

Dietary Intake. Subjects were instructed by a dietitian to complete a food record on 3 nonconsecutive days (2 week days and one weekend day) during the first and last week of the intervention (weeks 3–14). Subjects were given specific instructions regarding how to estimate portion sizes and identify all food and fluid intake; food models were viewed by subjects to enhance precision. Total energy intake, protein, carbohydrate, and lipid content were calculated using nutrition analysis software (Version 3.1.4; Avanutri Processor Nutrition Software, Rio de Janeiro, Brazil). All subjects were asked to maintain their normal food and fluid consumption throughout the study period.

Statistical Analyses

Normality of data was checked by the Shapiro-Wilk's test. Nonnormal variables were analyzed with $\log_{10}$ adjustment. Analysis of variance was used to compare descriptive characteristics between groups at baseline. Analysis of covariance of the raw difference between preintervention to postintervention measures with baseline values as a covariate was used for comparing changes within and between groups on muscular strength and body composition, in which interpretation of data was based on 95% confidence intervals (i.e., when 95% CI of the raw delta did not overlap the 0, there was a difference between baseline score). p values for the group comparisons are also presented. Repeated-measures analysis of variance was used for comparisons on dietary intake. Levene's test was used to analyze the homogeneity of variances. For all analyses, a $p \leq 0.05$ was accepted as statistically significant. The effect size (ES) was calculated as the post-training mean minus the pre-training mean divided by the pooled pre-training *SD* (7). An ES of 0.20–0.49 was considered as small, 0.50–0.79 as moderate, and >0.80 as large (7). Analysis of the individual relative changes was calculated through the percentage delta ([post-training × 100/pre-training] − 100). The data were expressed as mean values, *SD*s, and 95% CIs. The data were stored and analyzed using SPSS software version 24.0 (SPSS Inc., Chicago, IL, USA).

Results

No significant between-group differences were detected in baseline characteristics (age, body mass, height, and BMI). No significant differences ($p > 0.05$) were found between or within groups in regard to dietary intake during intervention (Table 1). Training attendance was not statistically different between G2x and G3x (96 ± 6% vs. 95 ± 7%, respectively; $p = 0.494$).

Table 1

Dietary intake at weeks 1 and 12 of intervention.*†

	G2x (*n* = 23)	G3x (*n* = 24)	*p*
Energy (kcal)			
Week 1	1,382.60 ± 207.81	1,406.06 ± 185.32	
Week 12	1,400.61 ± 148.38	1,371.90 ± 190.44	0.494
Energy (kcal·kg^{-1}·d^{-1})			
Week 1	22.51 ± 4.79	23.68 ± 5.4	
Week 12	22.61 ± 4.05	23.17 ± 5.53	0.767
Protein (g·kg^{-1}·d^{-1})			
Week 1	0.93 ± 0.30	1.01 ± 0.31	
Week 12	0.98 ± 0.23	0.97 ± 0.31	0.783
Carbohydrate (g·kg^{-1}·d^{-1})			
Week 1	3.22 ± 0.82	3.34 ± 0.90	
Week 12	3.08 ± 0.60	3.29 ± 0.89	0.460
Lipid (g·kg^{-1}·d^{-1})			
Week 1	0.66 ± 0.18	0.70 ± 0.20	
Week 12	0.71 ± 0.15	0.68 ± 0.19	0.368

*G2x = group that performed resistance training twice weekly; G3x = group that performed resistance training thrice weekly.
†Data are presented as mean ± *SD*. *p* values refer to interaction effects.

Changes in 1RM performance and body composition are presented in Table 2. There were no significant between-group differences in any analyzed variable ($p > 0.05$). The 1RM scores increased similarly and significantly compared with baseline for both groups in the chest press (ES = G2x: 0.73, G3x: 0.71) and knee extension (ES = G2x: 0.96, G3x: 0.61). For body composition, both training groups increased lean soft-tissue mass (ES = G2x: 0.17, G3x: 0.17), whereas only G3x significantly reduced body fat (ES = G2x: −0.02, G3x: −0.12). Individual percentage changes from pre-RT to post-RT for lean soft-tissue and fat mass are presented in Figure 1.

Discussion

The main finding of the current study was that performing RT 2 or 3 times per week with an equated number of weekly sets resulted in a similar increase in muscular strength and lean soft-tissue mass. Alternatively, the higher frequency condition also improved body fat in older women. To the best of our knowledge, this is the first study that investigated different frequencies with equated volume in older adults. With respect to muscular outcomes, the data confirm our initial hypothesis and are consistent with the current body of literature on the topic in younger populations (17,23). The magnitude of increases in strength and lean soft-tissue mass were consistent with previous RT data from a similar sample (9,20). However, given that no study to date has investigated the influence of training frequency under volume-matched conditions on these outcomes in elderly subjects, we have no basis of comparison with the literature.

It is interesting to note that even without controlling the training volume, most studies comparing 2 and 3 RT sessions per week in older adults showed no difference in the main studied outcomes, even in long-duration interventions (4,21,27). Although recent meta-analyses show that higher frequency training under conditions where volume is not equated promotes modestly greater the gains in muscle strength (17) and mass (23) when compared with lower frequency training, subanalyses of data showed very similar improvements in both outcomes when specifically comparing the effects of performing RT 2 vs. 3 times per week. That is, Grgic et al. (17) showed that in middle-aged and

Table 2

Raw values at pre- and post-12 weeks of intervention and adjusted mean differences for muscular strength and body composition according to groups.*†

	G2x (*n* = 23)	G3x (*n* = 24)	
Bench press 1RM (kg)			
Pre	28.8 ± 4.4	27.7 ± 4.9	
Post	32.2 ± 4.7	31.0 ± 5.8	ES = −0.02
Adjusted mean difference	3.38 (2.37, 4.39)‡	3.31 (2.31, 4.29)‡	*p* = 0.76
Knee extension 1RM (kg)			
Pre	23.6 ± 3.8	24.2 ± 4.7	
Post	27.7 ± 3.9	26.8 ± 4.3	ES = −0.36
Adjusted mean difference	4.07 (3.08, 5.06)‡	2.65 (1.68, 3.62)‡	*p* = 0.06
Body mass (kg)			
Pre	62.5 ± 7.9	61.0 ± 8.8	
Post	63.0 ± 8.1	60.9 ± 9.0	ES = −0.06
Adjusted mean difference	0.50 (−0.06, 0.94)	−0.09 (−0.52, 0.33)	*p* = 0.06
Lean soft tissue (kg)			
Pre	35.5 ± 3.5	34.7 ± 3.6	
Post	36.1 ± 3.3	35.3 ± 4.1	ES = 0.01
Adjusted mean difference	0.64 (0.28, 1.00)‡	0.59 (0.23, 0.94)‡	*p* = 0.83
Body fat (kg)			
Pre	25.1 ± 6.4	24.3 ± 6.8	
Post	24.9 ± 6.9	23.6 ± 6.7	ES = 0.10
Adjusted mean difference	−0.16 (−0.49, 0.36)	−0.74 (−1.16, −0.32)‡	*p* = 0.09
Body fat (%)			
Pre	39.4 ± 6.5	39.2 ± 6.4	
Post	38.9 ± 7.2	38.2 ± 6.4	ES = 0.08
Adjusted mean difference	−0.49 (−1.26, 0.19)	−0.98 (−1.48, −0.49)‡	*p* = 0.16

*ES = effect size (G3xES minus G2xES); G2x = group that performed resistance training twice weekly; G3x = group that performed resistance training thrice weekly; RM = repetition maximum.
†Prevalue and postvalue are presented as mean ± *SD*, and adjusted means as mean (lower, upper bound of 95% confidence interval). *p* values refer to ANCOVA's group effects.
‡Different to pre-training.

older adults the difference in ES for strength gains between 2× vs. 3×/week was 0.05 (trivial), whereas Schoenfeld et al. (23) similarly reported trivial ES differences (ES = 0.07) for gains in muscle mass between 3×+/week induces compared with 2×/week. Thus, these findings would seem to be of minimal practical meaningfulness. It should be noted that direct measures of hypertrophy (e.g., magnetic resonance imaging [MRI] and ultrasound) are specific to the muscle studied, and results cannot necessarily be extrapolated to other muscles.

A relevant aspect of our work is that we collected data about the subjects' habitual dietary intake, as opposed to previous studies on training frequency in elderly individuals (14,15,21,27,29). It therefore remains possible that results in these studies may have been influence by differences in caloric or macronutrient intake between or within groups, which would have confounded the ability to determine causality as to the effects of RT frequency on muscular adaptations. Given that no differences were found in dietary intake before and after the

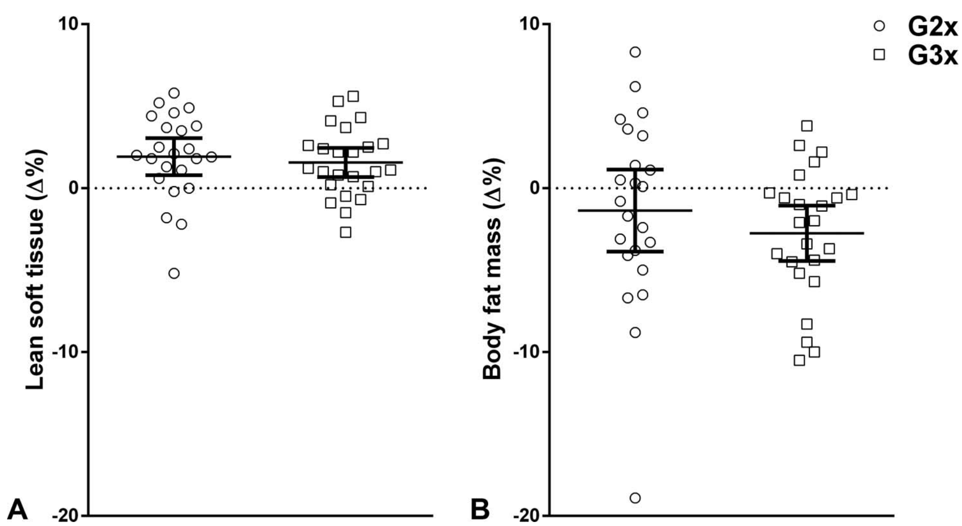

Figure 1. Individual percentage changes from pre-RT to post-RT for lean soft-tissue (panel A) and body fat mass (panel B) according to training groups. Data are presented as mean and 95% confidence intervals. RT = resistance training.

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intervention period in our study (Table 1), it can be inferred that nutritional factors did not influence the changes in outcomes found herein, especially morphological data.

In regard to body fat, only the G3x reduced fat mass from baseline after conclusion of the training protocol; however, the difference between groups was of trivial magnitude (ES: 0.10) and thus of questionable practical relevance. It is important to note that neither physical activity nor sedentary behavior was monitored during the experiment, hindering our ability to determine whether they may have exerted an undue influence on changes in the measured variables across the study period. Further research is warranted to help elucidate how RT frequency may influence changes in fat mass.

A limitation of our study is the use of the dual-energy x-ray absorptiometry which, although considered a reference standard for measuring body composition (5), may lack the sensitivity to detect subtle changes in muscle mass compared with more direct imaging measures such as computed tomography and MRI. Thus, caution should be observed when comparing/contrasting our findings with other studies that used direct measurements of muscle mass. In addition, the lack of a control group would be required to determine a true ES of the intervention, although RT has been shown to be an effective interventional strategy for improving the variables analyzed herein (9,28). However, our sample was larger than most previous studies on the topic (14,18,21,27), thereby affording better statistical power to draw relevant inferences.

We conclude that 12 weeks of RT increase muscular strength and lean soft tissue in untrained older women regardless of training frequency under weekly sets-equated conditions. However, reductions in body fat were only noted when training 3 times per week.

Practical Applications

From a practical standpoint, these results further our understanding as to the manipulation of resistance exercise variables when developing programs for older women. A flexible approach to training frequency can be used according to individual preferences when aiming muscular adaptations at initial stages of a RT program; however, when reducing body fat is the aim, increasing the training frequency (and holding the weekly sets constant) is recommended. Resistance training prescription should consider an individual's lifestyle and availability of daily time and days during the week for a training session because this may improve adherence and motivation to exercise.

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