Comparision of Low and High Volume of Resistance Training on Body Fat and Blood Biomarkers in Untrained Older Women: A Randomized Clinical Trial

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Abstract

Cunha, PM, Tomeleri, CM, Nascimento, MA, Mayhew, JL, Fungari, E, Cyrino, LT, Barbosa, DS, Venturini, D, and Cyrino, ES. Comparision of low and high volume of resistance training on body fat and blood biomarkers in untrained older women: a randomized clinical trial. *J Strength Cond Res* 35(1): 1–8, 2021—The purpose of this study was to compare the effects of resistance training (RT) performed with 2 different volumes on body fat and blood biomarkers in untrained older women. Sixty-five physically independent older women (≥60 years) were randomly assigned to one of 3 groups: low-volume (LV) training group, high-volume (HV) training group, and a control group. Both training groups performed RT for 12 weeks, using 8 exercises of 10–15 repetitions maximum for each exercise. The low-volume group performed only a single set per exercise, whereas the HV group performed 3 sets. Anthropometric, body fat (%), trunk fat, triglycerides (TG), total cholesterol, low-density lipoprotein cholesterol (LDL-c), high-density lipoprotein cholesterol, very LDL-c (VLDL-c), glucose (GLU), C-reactive protein (CRP), and composite Z-score were measured. The HV group obtained greater improvements compared with the LV group ($p < 0.05$) for TG (LV = −10.5% vs. HV = −16.6%), VLDL-c (LV = −6.5% vs. HV = −14.8%), GLU (LV = −4.7% vs. HV = −11.1%), CRP (LV = −13.2% vs. HV = −30.8%), % body fat (LV = −2.4% vs. HV = −6.1%), and composite Z-score (LV = −0.13 ± 0.30 vs. HV = −0.57 ± 0.29). Trunk fat was reduced ($p < 0.05$) only in the HV group (−6.8%). We conclude that RT performed in higher volume seems to be the most appropriate strategy to reduce body fat (%), trunk fat, improve blood biomarkers, and reduce composite Z-score in older women.

Key Words: aging, training volume, lipoproteins, strength training

Introduction

Aging is a natural process usually accompanied by several modifications (morphological, neuromuscular, metabolic, physiological, cognitive, and behavioral), which can affect the health and quality of life of the elderly (4,8,10,43). Therefore, aging process is associated with important changes in body composition, with emphasis to the increase in visceral fat and reduction of muscle mass (8,43). The increase in body fat has a critical impact on the health status of older populations whereby the accumulation of visceral fat can provoke important deleterious effects such as metabolic disfunctions, chronic diseases, lower muscle strength, difficulty in locomotion, and loss of balance (3,23).

Negative changes in lipid profile, increase in the concentrations of inflammatory biomarkers (e.g., C-reactive protein [CRP]), and glucose metabolism changes are related to development of chronic diseases (38,43). This scenario may be exacerbated in older women due to menopause, which may accentuate the negative changes in body composition and metabolic profile (24).

Physical exercise has been recommended as an important nonpharmacological strategy to attenuate these age-related impairments in health status (12). Among the different types of physical exercise, resistance training (RT) is a well-known approach that produces increases in muscle strength and growth (2). In addition, more recent evidence has shown that RT can be an effective strategy for reducing body fat (9,40), enhancing lipid profile (7,15), and reducing concentrations of CRP (33,40), all of which are important independent indicators of mortality for cardiovascular and metabolic diseases (16,17).

The magnitude of responses induced by RT may be influenced by the manipulation of variables that compose training programs, such as volume and intensity (19,20,35). Among the variables that can affect these components, the number of sets can have a major impact, with single sets allowing for use of heavier loads, providing higher intensity training at a lower volume (18) and requiring a shorter duration of the training session. On the other hand, use of multiple sets and, consequently, lower loads tends to increase training volume and produce greater metabolic stress, although it results in greater duration of training sessions (18,34). In this sense, the literature indicates that there may be an important dose-response relationship between load and training volume that mediates the adaptations caused by RT (22,33,37). Nunes et al. (27), for example, compared the effect of 3 vs. 6 sets per exercise on blood biomarkers (IL-6, TNF-α, low-density lipoprotein cholesterol [LDL-c], HbA1) and found that higher RT

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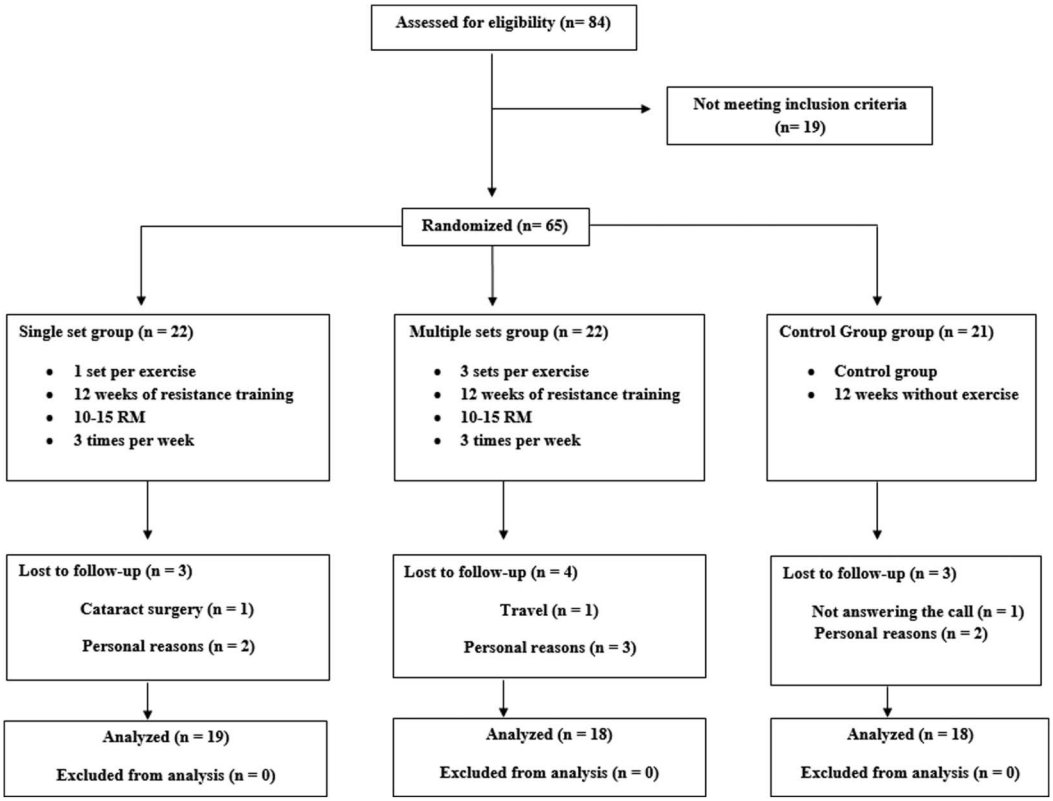

Figure 1. Flowchart of study. RM = repetitions maximum.

volume was necessary to improve these variables. Although high volume has shown better adaptations in these variables, this can be a limiting factor for adherence to the exercise (31).

To the best of our knowledge, there are no studies that have compared the effect of low (1 set) vs. high (3 sets) volumes of RT on blood biomarkers in untrained older women. Therefore, the purpose this study was to investigate the effects of RT programs performed at 2 different volumes (low and high) on relative body fat, trunk fat, lipid profile, blood glucose (GLU), and CRP in untrained older women. In addition, a second purpose was to assess the relationship between changes in body fat and blood biomarkers. Our hypothesis was that a higher RT volume would promote greater improvements in these variables.

Methods

Experimental Approach to the Problem

The total duration of the study was 16 weeks, of which the first 2 weeks (1–2 weeks) were used for familiarization with the RT program exercises and pre-training measures, whereas the last 2 weeks (weeks 15–16) were intended for post-training measurement. A supervised progressive RT program was performed between weeks 3–14 by low-volume (1 set) and high-volume (3 sets) training groups. A control group (CG) did not perform any type of structured exercise program during this period. Anthropometric measures, body fat, lipid profile, CRP, and blood glucose were obtained before and after training. The schedule of subjects' evaluations was similar at pre-training and post-training, thereby helping to ensure consistency and thus internal validity. The post-training measurements were performed at least 72 hours after the final RT session to avoid any acute effects of the last RT session.

Subjects

Eighty-four physically independent and untrained older women (>60 year old) with no experience with this type of exercise volunteered to participate. The sample was primarily selected through interview or clinical referrals. As initial inclusion criteria, subjects were required to be older than 60 years of age, female, and physically independent, free from cardiac or orthopedic dysfunction, which could impede physical exercise. In addition, they had not been involved in systematic practice of regular physical activity more than once a week over the past 6 months preceding the beginning of the study. Furthermore, subjects could not have uncontrolled diabetes, uncontrolled hypertension, or be undergoing hormone therapy. Finally, only those subjects who were evaluated by a cardiologist and released for the practice of RT without any restrictions were accepted. Thus, 65 subjects signed a written informed consent form at the beginning of the study. This investigation was conducted according to the Declaration of Helsinki and was approved by the State University of Londrina ethics committee.

A blinded researcher was responsible for generating random numbers (computer-generated random numbers) for subject allocation. Subjects were randomly assigned to one of 3 treatment groups: a low-volume (LV) group (n = 22), a high-volume (HV) group (n = 22), and a CG (n = 21). Both training groups performed an RT program composed of 8 whole-body exercises performed with a 10–15 repetition maximum per sets for 12 weeks. The CG was oriented to maintain their routine of daily activities and not participate in any structured exercise program during the study period. If any subject of the LV or HV group did not reach 85% adherence, they would be excluded from the statistical analysis. Figure 1 presents a schematic representation of subject recruitment and allocation in this study.

Information about the use of medications was obtained of the subjects in the preintervention and postintervention periods. No case of changes in medication was observed over time; thus, changes found here can be associated with intervention. The medications more used by the subjects were as follows: statins, beta blockers, ACE—inhibitors/angiotensin II-antagonists, antidiabetic agents, alendronate sodium, and duloxetine hydrochloride.

Procedures

Anthropometry. Body mass and height were measured using a calibrated electronic scale (Balmak Labstore, Curitiba, PR, Brazil), with subjects wearing light workout clothing and no shoes. Body mass index was calculated as the body mass in kilograms divided by the square of the height in meters. The measurements were performed during the morning period (from 7:00 to 9:00 AM).

Body Composition. Dual-energy X-ray absorptiometry (Lunar Prodigy, model NRL 41990; GE Lunar, Madison, WA) was used to assess relative body fat and trunk fat. Calibration of the equipment followed the manufacturer's recommendations, and both calibration and analysis were performed by a laboratory technician with experience in this type of evaluation. Subjects were submitted to the examinations wearing light clothes, barefoot, and without any metallic object or any other accessory items on their body. Those surveyed lay flat on the scanning table until finalization of the measure. Individual scans were evaluated for lean and soft tissues for the whole body and specific regions (trunk and upper and lower limbs). The limbs were separated from the trunk and head by standard lines generated by the software of the equipment. Demarcation lines were adjusted by the technician through specific anatomical points, as denoted in the equipment manual. Previous test-retest scans of 12 older women measured 24–48 hours apart resulted in a technical error of measurement of 0.23 kg for body fat and intraclass correlation coefficients >0.99. The measurements were performed during the afternoon period (from 13:00 to 16:00 PM).

Biochemical Analysis. Subjects rested in a seated position for at least 5 minutes before withdrawal of 5 ml of blood from a prominent superficial vein in the antecubital space using a clean venous puncture with minimal stasis. Samples were collected into 1 tube between 7:00 and 9:00 AM after a 12-hour fast and after a minimum of 72 hours since the last RT session. The sample was placed in a tube containing a dipotassium ethylenediaminetetraacetic acid as an anticoagulant and preservative. All samples were centrifuged at 3,000 rpm for 15 minutes, and plasma or serum aliquots were stored at −80° C until assayed. Interassay and intraassay coefficients of variation were <10% as determined in human plasma. Measurements of serum levels of high-sensitivity CRP, GLU, total cholesterol (TC), high-density lipoprotein cholesterol (HDL-c), and triglycerides (TG) were determined by standard methods in a specialized hospital laboratory. The LDL-c was calculated using the Friedewald et al. (11) equation: LDL-c = TC − (HDL-c) − (TGL/5). The analyses were performed using a biochemical autoanalyzer system (Dimension RxL Max—Siemens Dade Behring, Erlangen, Germany) according to established methods in the literature consistent with the manufacturer's protocol.

Table 1
General characteristics of the sample at baseline (n = 55).

	CG (n = 18)	LV (n = 19)	HV (n = 18)	p
Age (y)	69.0 ± 4.2	70.3 ± 6.3	68.7 ± 4.7	0.67
Body mass (kg)	63.9 ± 11.9	68.6 ± 16.0	63.2 ± 12.4	0.43
Height (cm)	155.1 ± 5.9	156.4 ± 7.4	154.6 ± 5.2	0.65
Body mass index (kg·m^{-2})	26.5 ± 4.5	27.9 ± 5.2	26.5 ± 5.0	0.59
Medical history*				
Type 2 diabetes (%)	11	11	5	0.50
Hypertension (%)	56	53	56	0.85
Dyslipidemia (%)	33	26	39	0.56
Fibromyalgia (%)	0	11	11	0.33

CG = control group; LV = low-volume training group; HV = high-volume training group.
*The chi-square test.
The physical characteristic values are displayed as mean ± *SD*. The medical history is presented as percentage.

Composite Z-score. The z-score of the percentage changes (from pre-training to post-training) of the raw data for each parameter was calculated. Subsequently, a composite Z-score derived from the average of the component z-scores was calculated using the following formula: ([HDL-c z-score] + [LDL-c z-score] + very LDL-c [VLDL-c z-score] + [TC z-score] + [TG z-score] + [GLU z-score] + [CRP z-score])/7. The z-score was calculated for each variable using individual data and standard deviations of data for the entire group. The equation used to calculate the composite z-score was an adaptation of the method of Conceição et al. (7).

Resistance Training Program. The RT program was performed over time of 12 weeks in the morning period based on recommendations to improve strength and muscular endurance in the older adults (1,12). Each subject was individually supervised by physical education professionals to maintain the quality of execution of the study protocol and to ensure safety. The sessions were performed 3 times per week on Mondays, Wednesdays, and Fridays.

The RT program was performed on machines and free weights and included 8 exercises for different body segments (arms, legs, and trunk) that were performed in the following order: chest press, horizontal leg press, seated row, knee extension, preacher curl (free weights), leg curl, triceps pushdown, and seated calf raise. Subjects trained by performing a 10–15 repetitions maximum (RM) in a single set per exercise in the LV group and 3 sets per exercise in the HV group. Subjects were instructed to inhale during the eccentric phase and expire during the concentric phase of each exercise, maintaining the speed of movements in a 1:2 proportion (concentric and eccentric contraction, respectively). The rest interval between sets in the HV group was 60–120 seconds. The transition interval between exercises was 2–3 minutes for both groups. Loads were individually adjusted for each exercise during the whole training period whenever the upper limit of programmed repetitions (15RM) was reached in 2 consecutive sessions in the LV group or in 3 consecutive sessions in the HV group. The load increases were in the range of 2–5% for upper limb exercises and 5–10% for lower limb exercises, as recommended in the literature (12). The duration of each session was approximately 15–20 minutes for the LV group and 45–60 minutes for the HV group. Total training volume for each exercise was calculated by the following equation: number of sets × repetition × load. Weekly volume was calculated by adding the values for all exercises (35).

Dietary Intake. Subjects were instructed by a dietitian to complete a food record on 3 nonconsecutive days (2-week days and 1 weekend day) in the first and last week of the intervention period.

Table 2
Dietary intake at the pre-training to post-training period (12 weeks) according to groups in older women.

	CG (n = 18)	LV (n = 19)	HV (n = 18)	Interaction, p value
Energy (kcal·kg^{-1}·d^{-1})				
Pre-training	16.5 ± 15.4	15.4 ± 4.5	17.5 ± 6.0	
Post-training	15.4 ± 6.9	15.3 ± 3.7	15.8 ± 6.3	0.62
Protein (g·kg^{-1}·d^{-1})				
Pre-training	0.6 ± 0.3	0.7 ± 0.3	0.8 ± 0.4	
Post-training	0.7 ± 0.4	0.7 ± 0.3	0.8 ± 0.4	0.24
Carbohydrate (g·kg^{-1}·d^{-1})				
Pre-training	2.3 ± 1.1	2.2 ± 0.7	2.7 ± 0.8	
Post-training	2.1 ± 0.9	2.1 ± 0.7	2.4 ± 0.6	0.88
Lipids (g·kg^{-1}·d^{-1})				
Pre-training	0.4 ± 0.2	0.4 ± 0.1	0.4 ± 0.2	
Post-training	0.4 ± 0.3	0.4 ± 0.2	0.4 ± 0.2	0.80

CG = control group; LV = low-volume training group; HV = high-volume training group.
Data are expressed as mean and *SD*.

Subjects were given specific instructions regarding the recording of portion sizes and quantities to identify all food and fluid intake, in addition to viewing food models to enhance precision. Total dietary energy, protein, carbohydrate, and lipid content were calculated using nutrition analysis software (Avanutri Processor Nutrition Software, Version 3.1.4, Rio de Janeiro, Brazil). All subjects were asked to maintain their normal diet throughout the study period.

Statistical Analyses

Sample size was estimated using G*Power (version 3.0.10, Universitat Kiel, Germany). Data from previous studies from our laboratory in which RT was the exercise intervention model were used for sample size estimation (33,39,40). We based the calculation on an effect size (ES) of 0.30, an α level of 0.05, and a power $(1 - \beta)$ of 0.95. The sample size estimation indicated that it would be necessary to include at least 45 subjects (15 per group). Considering a drop-out rate, we recruited 65 older women who were randomly assigned into one of 3 groups of the study.

Normality of all data was checked using the Shapiro-Wilk test. Levene's test was used to analyze the homogeneity of variance. One-way analysis of variance (ANOVA) and chi-square tests were used to compare the control and intervention groups regarding the general characteristics and clinical conditions (categorical variables), respectively. For the comparisons of baseline total training volume between training groups (LV and HV), an independent t-test was used. Two-way analysis of covariance for repeated measures was applied for comparisons between groups, with pre-training scores used as covariates (36,41). When an F-ratio was significant, Bonferroni's *post hoc* test was used to identify mean differences. Effect size was calculated to verify the magnitude of the differences using Cohen's d, where an ES of 0.20–0.49 was considered as small, 0.50–0.79 as moderate, and ≥0.80 as large (6). To verify the differences among groups as percentage changes and composite Z-scores, a 1-way ANOVA was applied; when the F-ratio was significant, a Bonferroni post hoc test was used to identify the mean differences. Pearson correlation was used to determine the relationships between percentage changes in total body fat or trunk fat and percentage changes in blood biomarkers. Significance was set at $p \leq 0.05$. Data were analyzed using STATISTICA software version 10.0 (StatSoft Inc., Tulsa, OK).

Table 3
Subjects' scores at preintervention and postintervention.

	CG (n = 18)			LV (n = 19)			HV (n = 18)			
	Pre	Post	ES	Pre	Post	ES	Pre	Post	ES	Interaction, p value
TC (mg·d^{-1}·L^{-1})	203.4 ± 27.9	219.8 ± 25.9	+0.61	212.0 ± 45.3	190.6 ± 33.4*†	−0.54	219.9 ± 29.7	187.6 ± 28.3*†	−1.11	<0.001
TG (mg·d^{-1}·L^{-1})	107.1 ± 34.7	125.7 ± 39.6	+0.50	127.0 ± 57.1	113.7 ± 46.4	−0.26	113.6 ± 42.5	94.7 ± 31.4*†‡	−0.51	<0.001
LDL-c (mg·dl^{-1})	121.2. ± 26.3	142.8 ± 28.3*	+0.79	123.5 ± 38.8	99.8 ± 26.7*†	−0.72	141.7 ± 26.2	115.4 ± 22.0*†	−1.09	<0.001
HDL-c (mg·dl^{-1})	55.10 ± 13.41	54.10 ± 12.32	−0.09	57.2 ± 16.6	56.8 ± 15.5	−0.02	55.8 ± 19.1	57.8 ± 21.0	+0.10	0.12
VLDL-c (mg·dl^{-1})	22.90 ± 8.34	24.64 ± 8.92	+0.20	24.7 ± 10.5	23.1 ± 8.8	−0.17	21.6 ± 8.9	18.4 ± 6.5*†‡	−0.41	<0.001
GLU (mg·dl^{-1})	91.05 ± 11.07	96.57 ± 9.17*	+0.55	102.4 ± 15.9	97.6 ± 14.6*	−0.31	100.0 ± 11.7	88.9 ± 12.0*†‡	−0.93	<0.001
CRP (mg·L^{-1})	2.77 ± 1.47	2.98 ± 1.64	+0.14	3.8 ± 1.8	3.3 ± 1.6	−0.30	3.9 ± 1.8	2.7 ± 1.3*†	−0.71	0.001
Body fat (%)	40.19 ± 7.02	41.01 ± 6.68	+0.12	37.4 ± 6.7	36.5 ± 6.9*†	−0.12	39.5 ± 7.1	37.1 ± 7.0*†‡	−0.34	<0.001
Trunk fat (kg)	13.23 ± 4.80	13.39 ± 4.61	+0.03	14.3 ± 5.7	13.6 ± 5.6	−0.12	8.8 ± 3.4	8.2 ± 3.31*†	−0.18	<0.001

CG = control group; LV = low-volume training group; HV = high-volume training group; ES = effect size; TC = total cholesterol; TG = triglycerides; LDL-c = low-density lipoprotein cholesterol; HDL-c = high-density lipoprotein cholesterol; VLDL-c = very low-density lipoprotein cholesterol; GLU = glucose; CRP = C-reactive protein.
*$p < 0.05$ vs. pre.
†$p < 0.05$ vs. CG.
‡$p < 0.05$ vs. LV.
Data are presented as mean and *SD*.

Table 4
Adjusted mean by analysis of covariance to post-test.

		CG (n = 18)		LV (n = 19)		HV (n = 18)	
	Covariate mean	Mean	95% CI	Mean	95% CI	Mean	95% CI
TC ($mg \cdot d^{-1} \cdot L^{-1}$)	211.6	220.3	208.4–232.1	190.4	179.0–201.7	183.3	171.1–195.4
TG ($mg \cdot d^{-1} \cdot L^{-1}$)	115.9	132.7	120.2–145.1	106.9	94.6–119.2	96.3	83.9–108.7
LDL-c ($mg \cdot dl^{-1}$)	128.6	142.4	131.0–153.9	102.1	90.9–113.2	110.5	97.7–123.3
HDL-c ($mg \cdot dl^{-1}$)	56.1	54.7	52.5–57.0	55.9	53.6–58.1	58.1	55.9–60.4
VLDL-c ($mg \cdot dl^{-1}$)	23.0	24.7	23.4–26.0	21.7	20.3–23.0	19.6	18.2–21.0
GLU ($mg \cdot dl^{-1}$)	97.7	102.5	99.2–105.9	93.9	90.9–96.9	87.0	84.0–89.9
CRP ($mg \cdot L^{-1}$)	3.5	3.3	3.0–3.6	3.1	2.7–3.4	2.5	2.2–2.8
Body fat (%)	38.2	39.9	39.3–40.4	38.1	37.6–38.7	36.6	36.0–37.2
Trunk fat (kg)	12.2	12.4	12.1–12.7	11.6	11.3–11.8	11.4	11.1–11.8

CG = control group; LV = low-volume training group; HV = high-volume training group; CI = confidence interval; TC = total cholesterol; TG = triglycerides; LDL-c = low-density lipoprotein cholesterol; HDL-c = high-density lipoprotein cholesterol; VLDL-c = very low-density lipoprotein cholesterol; GLU = glucose; CRP = C-reactive protein.

Results

General characteristics and medical history of the subjects are described in Table 1. There was no significant difference among groups ($p > 0.05$) for general characteristics and medical history at baseline.

There were no significant ($p > 0.05$) main effects for total energy and macronutrient daily intake, indicating there were no differences between groups and no changes over time (Table 2).

Table 3 presents pre-training and post-training blood biomarkers, percentage body fat, and trunk fat. A group vs. time interaction ($p < 0.05$) revealed the effectiveness of high volume of RT for the improvement of all variables analyzed, except for HDL-c ($p > 0.05$). In addition, statistically significant differences ($p < 0.05$) were found in favor of the HV group when compared with the LV group for TG, VLDL-c, GLU, CRP, and relative body fat. The ES for the HV group was substantially larger than for the LV group for all variables investigated. The covariate mean values and the adjusted post-training scores are presented in Table 4.

The composite Z-scores for percent changes from pre-training to post-training according to groups are presented in Figure 2. The HV group presented greater changes than both LV and CG groups ($p < 0.05$), whereas the LV group had greater changes ($p < 0.05$) in comparison with the CG group's composed Z-score (HV = -0.57 ± 0.29; LV = -0.13 ± 0.30; CG = 0.70 ± 0.50).

Except for HDL-c, all other blood biomarkers exhibited significant positive correlations with changes in relative body fat ($p < 0.05$) and trunk fat ($p < 0.05$) as shown in Figure 3. The highest correlation was found between GLU and relative body fat ($r = 0.66$). High-density lipoprotein cholesterol did not exhibit any significant correlation ($p > 0.05$) with change in trunk or relative body fat.

The total training volumes for weeks 1, 4, 8, and 12 according to groups are presented in Figure 4. As expected, the HV group exhibited greater values for total training volume than the LV group in all moments ($p < 0.05$), although the progression has been similar.

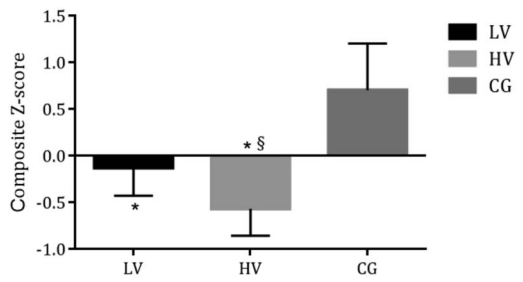

Figure 2. Composite Z-score of the percentage changes from pre-training to post-training of the cardiovascular and metabolic disease components according to groups in older women. *$p < 0.05$ vs. pre. §$p < 0.05$ vs. control group. †$p < 0.05$ vs. LV. LV = low-volume training group; HV = high-volume training group; CG = control group.

Discussion

The main finding of this study was that an RT program performed in high-volume (3 sets for exercise) for 12 consecutive weeks was more efficient to reduce TG, VLDL-c, GLU, CRP, and relative body fat than low-volume training (1 set for exercise) in untrained older women. In addition, the magnitude of the responses was higher in the HV group for all variables analyzed when compared with the LV group and, therefore, confirmed our initial hypothesis that higher training volumes can be superior to low-volume training in initial adaptive responses to RT in older women. However, a 12-week RT program with low-volume seems to be enough to reduce TC, LDL-c, and relative body fat, whereas a program with high-volume seems to be essential to reduce trunk fat.

Overall changes in blood biomarkers induced by RT were expressed by percentage changes using a composite Z-score technique. This approach may be an important tool to estimate the effect of training because it considers the overall response to an RT program, allowing to draw inferences of the intervention as whole as opposed to isolated outcomes. In this study, we found that 3 sets per exercise resulted in greater changes in the composite Z-score for the HV group compared with the LV group, suggesting that higher volume in RT is associated with greater positive improvements. Thus, these findings lend support to the importance of the practice of RT in older women as a means of enhancing overall health and forestalling the emergence of chronic diseases such as diabetes, hypertension, neurodegenerative diseases, various types of cancers, and cardiometabolic diseases (5,13,14). Therefore, the composite Z-score reduction illustrates an overall improvement of several risk factors for diseases that typically affect the older populations, and it may have an impact on clinical conditions (e.g., reductions in drug use, status health, and physical independence) and improvement in overall health status.

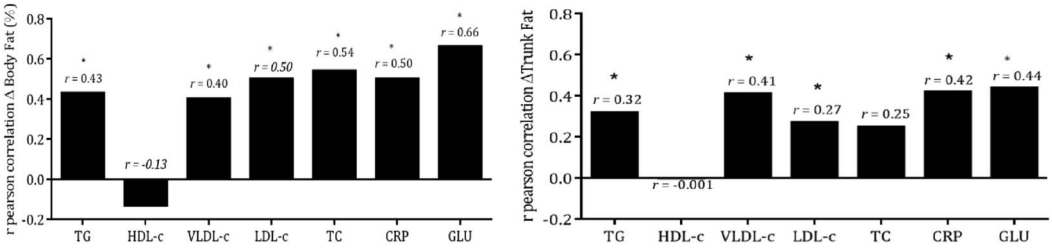

Figure 3. Correlations of body fat and trunk fat with biochemical variables. *$p < 0.05$. TC = total cholesterol; TG = triglycerides; LDL-c = low-density lipoprotein cholesterol; HDL-c = high-density lipoprotein cholesterol; VLDL-c = very low-density lipoprotein cholesterol; GLU = glucose; CRP = C-reactive protein.

To the best of our knowledge, this is the first study to compare different RT volumes using the 1- vs. 3-set protocols on these variables (i.e., body fat, lipid profile, glucose, and CRP). Because of this unique approach, it limits comparison with other studies. Some studies have used different dependent variables but also have shown greater response to higher volume (9,20), such as the results found in our study. On the other hand, there are studies that did not observe differences between 1 vs. 3 sets per exercise for body composition alterations (30,32). Although the reasons for these conflicting results are not clear, they may be related to factors such as differences in training protocols regarding volumes or intensities, in the characteristics of the subjects, or even in the variables analyzed. In this sense, Nunes et al. (27) reported that higher volumes may be more effective for modifying blood biomarkers. Therefore, more studies are needed to elucidate the issue of the effect of training volume on various health-related markers in older women.

It is interesting to note that in this study, we observed changes in the lipid profile of training subjects, with reductions in LDL-c, VLDL-c, TG, and CT, which support the benefits of RT for this population. The effectiveness of the RT response on the lipid profile has been shown in other studies with older subjects (7,33,40). Although our study was not able to identify the mechanisms responsible for these alterations, we can speculate that the relationship between the changes in body fat and LDL-c (Figure 3) suggests that reductions in one will affect the other (42). A similar pattern holds for other lipids with similar correlations between the change in body fat and various lipids (Figure 3). The association between body fat and lipid profiles may be related to insulin resistance and increased free fatty acids, a condition leading to formation of large TG-rich VLDL particles, which alters the expression of key enzymes in the plasma such as decreased lipoprotein lipase (42). In addition, the observed changes can be due to an increase in the ability of skeletal muscle to use fat, thereby reducing the levels of plasma lipids (25).

This study showed larger decreases in the glucose level in the HV group after intervention compared with the LV group. These results are in line with those found by Ribeiro et al. (32) and Tomeleri et al. (39). In both studies, 3 sets were performed per exercise, and, as in our study, reductions in the blood glucose level were found. Such reduction was expected because the glycolytic pathway is essential to generate energy when performing RT (21). In addition, another possible mechanism for glucose reduction may have been improvement in insulin sensitivity induced by RT (29).

Another variable of great importance analyzed in this study was CRP because it is an inflammatory marker and an independent indicator of cardiovascular diseases. The HV group produced over twice as much reduction CPR as did the LV group. This information corroborates works conducted by Ribeiro et al. (32) and Tomeleri et al. (39). One of the possible mechanisms responsible for such reductions is related to vigorous muscle contraction, which in turn produces anti-inflammatory substances that may act as antagonists to CPR, therefore helping to reduce its blood concentrations (28). In addition, changes in body composition found here may have had great impact on mediating of this inflammatory marker (40).

Our results also revealed that a high-volume RT was more efficient for decreased relative body fat in older women than low-volume RT, as shown in previous studies (9,32). The higher

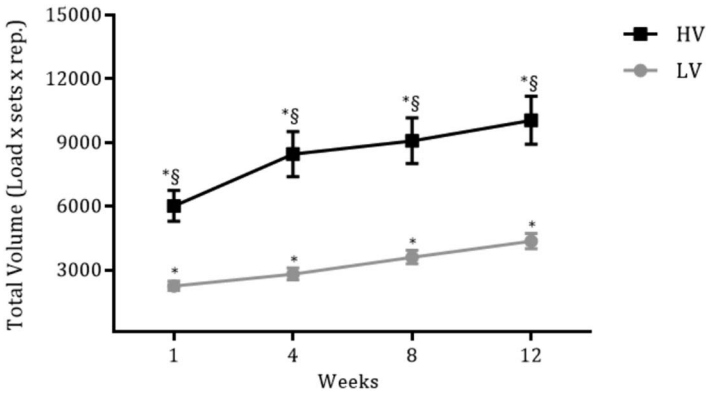

Figure 4. Total volume training in 1, 4, 8, and 12 weeks to groups LV and HV. *$p < 0.05$ vs. pre; §$p < 0.05$ vs. LV. HV = high-volume training group; LV = low-volume training group.

volume of training is likely to cause greater energy expenditure during the RT session (26), which in turn decreases body fat and can help improve blood biomarkers. Without alterations in diet (Table 2), subjects can be expected to lose mass as a result of RT due to reductions in body fat.

In this study, the higher reduction in the relative body fat and trunk fat in the HV group may have played an important role in modifications of the blood biomarkers. The higher volume of RT seems to better provoke alterations in blood biomarkers and decrease composite Z-score.

This study has some important limitations. The results reported here are specific to untrained older women and should not necessarily be extrapolated to other populations. We were not able to monitor physical activity levels outside of the study environment, which may have confounded results by increasing caloric expenditure and facilitation of muscle growth; however, all subjects were instructed to maintain their normal level of physical activity. Finally, our findings are limited to comparison between 1 vs. 3 sets in 8 specific exercises. Other exercises might elicit different findings.

The results of this study suggest that RT with high volume seems to be the most appropriate strategy for to improving of blood biomarkers, composite Z-score, relative body fat, and trunk fat in untrained older women.

The results of this study suggest that RT with high volume is more effective for improving blood biomarkers, composite Z-score, percentage body fat, and trunk fat in untrained older women.

Practical Applications

In summary, regular RT has been recommended to attenuate the deleterious effects of aging and promote health-related improvements in older adults (1). The results of this study showed that high-volume RT generated better adaptations compared with low-volume training in older women, indicating that greater volume is required to decrease GLU, TG, VLDL-c, and CRP concentrations. In addition, the high volume seems to be necessary to promote significant reductions in trunk fat. On the other hand, an RT program with low volume seems to be enough to reduce TC, LDL-c, and relative body fat. Future studies are warranted to verify the effects of manipulations of different training variables and the physiological mechanisms related to improvement of blood biomarkers induced by RT.

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