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Original Research

High Supervised Resistance Training in Elderly Women: The Role of Supervision Ratio

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ABSTRACT

International Journal of Exercise Science 13(3): 597-606, 2020. The objective of this study was to compare the effects of very high supervision (VHS-RT) versus high supervision (HS-RT) ratio resistance training (RT) on irisin, brain-derived neurotrophic factor (BNDF), muscle strength, functional capacity, and body composition in elderly women. Participants performed daily undulating periodized RT over 16 weeks with two different supervision ratios: VHS-RT at 1:2 (supervisor/subject) or HS-RT at 1:5. Serum was used to analyze brain derived neurotropic factor (BDNF) and irisin by enzyme-linked immunosorbent assay (ELISA). Body composition was evaluated by dual-energy X-ray absorptiometry, while functional capacity was evaluated using the Six-minute walk test, and Timed Up and Go (TUG). One- repetition maximum (1RM) was determined for bench press and 45º leg press exercises. For both groups, no differences between baseline and post-training were identified for irisin and lean mass ($p > 0.05$). Both groups improved bench press 1-RM, 45º leg press 1-RM, and TUG ($p < 0.05$). The VHS-RT group displayed higher effect sizes for 1-RM tests. Moreover, only VHS-RT group reduced body fat and body fat percentage ($p < 0.05$). In contrast, the HS-RT increased BDNF ($p < 0.01$). In this sense, RT enhances muscle strength and functional capacity in elderly women independent of supervision ratio. A greater supervision ratio during RT may induce more improvements in muscle strength, and body composition than lower supervision ratio during RT.

KEY WORDS: Aging, exercise, muscle strength, functional capacity

INTRODUCTION

Aging is associated with a decrease in muscle strength and muscle power that cause difficulties in performing activities of daily living (6, 14) and increases the risk of mortality (26). Furthermore, the progressive reduction of lean mass, and increase in fat mass with aging also contribute to reduced health and impaired capacity to live independently (6). In this regard, important serum markers during aging are related to health and physical function, such as irisin and brain derived neurotropic factor (BDNF) (2, 15, 16). Although the impact of aging on irisin concentrations remain unclear (16), irisin is associated with bone metabolism, and inversely correlated with the incidence of bone fracture (2). In contrast, a progressive decrease in BDNF serum concentrations is observed during aging, which may contribute to the deterioration of the neural system, and impaired neuromuscular function (15).

Nevertheless, resistance training (RT) is considered a non-pharmacological tool to attenuate the effects of aging (6), due to improvements in muscle strength (24), functional capacity (20), muscle power (14), body composition (10), cytokine profile (21), and serum irisin concentrations (17) in elderly individuals. Although RT is widely recommended during aging, supervision of exercises should be conducted by experienced trainers (23). Direct supervision, and the associated supervision ratio (supervisors: exercisers), may influence RT improvements (i.e. muscle strength, power, functional capacity, and quality of life) (18). Indeed, a high supervision ratio (i.e. 1 supervisor to 5 exercisers) during RT is better in improving knee extension torque than a low supervision ratio during RT (i.e. 1 supervisor to 25 exercisers) (12). Moreover, direct supervision (1:1) is more effective in inducing the aforementioned RT improvements than a low supervision ratio during RT (1:10) in the elderly (23). It has been well established in the literature that a high supervision ratio during RT is more effective than a low supervision ratio during RT (12, 18, 23). However, it remains unclear whether different proportions below the high supervision ratio threshold would influence RT improvements.

Investigations regarding high supervision ratios during RT is limited in elderly individuals with respect to muscle function (21), body composition (10), and serum biomarkers (17, 20). Thus, the purpose of the present study was to compare two high supervision groups with different ratios (1:2 and 1:5), and report measures of muscle strength, functional capacity, and cytokines in elderly women. The initial hypothesis is that a very high supervision ratio during RT results in more pronounced improvements in muscle strength and body composition.

METHODS

Participants

Twenty elderly postmenopausal women were randomly allocated into very high supervision (VHS-RT) and high supervision (HS-RT) groups (VHS-RT = 9 subjects; age = 64.00 ± 3.67 years; body mass = 64.06 ± 6.99 kg; height = 1.53 ± 0.05 meters; HS-RT = 11 subjects; age = 65.64 ± 5.32 years; body mass = 70.44 ± 12.19 kg; height = 1.53 ± 0.05 meters). Volunteers did not exercise regularly for the preceding six months before the study RT program. The exclusion criteria included the use of hormonal replacement, immunosuppressive therapy, inflammatory diseases, acute infection, and invasive procedures (catheterization, surgery). Elderly women above 60 years of age were included and instructed to maintain their normal diet regimen and encouraged to avoid the use of anti-inflammatory drugs during, and after the experimental trials and test days. Subjects completed a medical evaluation and when approved, signed an informed consent document approved by the Local University Research Ethics Committee. This research was carried out fully in accordance to the ethical standards of the International Journal of Exercise Science (19). A power analysis conducted *a priori* with G*POWER 3.1 (Universitat Kiel, Germany) reveled that a total sample size of the 20 subjects presented a power of 0.84, considering an effect size of 0.35 and an $\alpha = 0.05$.

Protocol

This was an experimental design with pre-intervention and post-intervention testing. Both tests were identical with respect to the assessment of muscle strength, functional capacity, body composition, and cytokines. Both groups performed the same RT program over 16 weeks at a frequency of two-times per week. Subjects were allocated randomly into the high supervision group (HS-RT: i.e. subjects trained with the assistance of one trainer for every five subjects) or the very high supervision group (VHS-RT: i.e. subjects trained with a ratio of one trainer for every two subjects). In the VHS-RT, exercisers had the opportunity to more closely follow load increments and received constant instruction on proper exercise technique. Participants in the HS-RT also had their load increments and exercise technique monitored.

The RT protocol was a daily undulating periodization for both groups. The training loads varied daily, and a different intensity was adopted for each training session according to the following sequence over the 16-week period: 12-14 RM, 10-12 RM, 8-10 RM, and 6-8 RM. The rest intervals between sets and exercises were as follows: 12-14 RM: 60s; 10-12 RM: 80s; 8-10 RM: 100s; and 6-8 RM: 120s (20). Training loads were selected and supervised by experienced trainers based on feedback about the feeling of perceived exertion, and technical ability of the subject. Moreover, in both groups, the loads were progressively increased, as subjects were able to perform the maximal number of repetitions established by the daily repetition maximal zone without concentric failure. RT exercises included bench press, 45º leg press, seated row, leg curl, biceps curl, hip abduction, seated calf raise, and abdominal crunches. Before the beginning of the daily undulating periodization training, subjects completed two weeks of RT acclimation. The familiarization protocol consisted of two sets of 15 repetitions.

All subjects completed the familiarization protocol on all exercises before the 1RM tests. During acclimation, standard instructions and explanations about the procedures of the test protocols, and the proper exercise technique were provided. The 1RM test was used to determine muscle strength of two exercises: 45° leg press and bench press. The 1RM protocol was conducted according to the procedures of Brown and Weir (2001). Prior to 1RM testing, two light warm-up sets were performed with 2-minute rest periods. Then, the participants had up to five attempts to achieve the 1RM load with five minutes of rest between attempts. 1RM loads were considered to be the maximum weight that could be lifted only once with proper technique. A ten-minute rest interval was provided between the 1RM evaluations for each exercise. Relative muscle strength was determined by the division of absolute values of 1RM load by body mass (22). To guarantee the stabilization of 1RM test values, the 1RM tests were determined on two separate days with 3 days between.

Functional capacity was assessed by the Timed Up and Go test (TUG) and the six-minute walk test. The TUG test consisted of rising from a chair, walking as fast as possible to a cone three meters away, and then returning to sit on the chair (31). The six-minute walk test was performed according to recommendations from the American Thoracic Society (2002) and required subjects to walk the greatest distance possible in six minutes through a 30 meter corridor.

Body fat, lean mass, and bone mineral content were assessed via dual energy x-ray absorptiometry (General Electric-GE model 8548 BX1 L, Lunar DPX type, Encore 2005 software; Madison, WI, USA). Body mass and height were measured by digital scale (W110H, Welmy, São Paulo, Brazil) and wall stadiometer (Sanny, Medical American of Brazil, São Paulo, Brazil).

With respect to biochemical assays, subjects reported to the laboratory between 08:00–10:00 am, after an overnight fast, and after blood collection from the antecubital vein, samples were centrifuged at room temperature at 2500 rpm for 10 min. All subjects were encouraged to avoid smoking, alcohol and caffeine consumption, as well as unusual physical activity to avoid any potential influence on biochemical parameters. Serum was stored at - 80°C until subsequent analysis. Serum was analyzed for BDNF (R&D System Inc., Minneapolis, MN, USA) and irisin (MyBioSource Inc., San Diego, CA, USA) using commercially available enzyme-linked immunosorbent assay (ELISA) kits according to manufacture instructions. All analyses were performed in the Immune Gerontology/ Molecular Biology Laboratory of Applied Exercise at the University. All samples were determined in duplicate to guarantee the precision of the results. The minimal detectable values were 184.38 pg/mL for BDNF, and 27.85 ng/mL for irisin.

Statistical Analysis

Data are presented as means ± standard deviation (SD). Normality was verified by the Shapiro-Wilk test. An independent *t*-test was used to compare pre-training dependent variables between groups. Training effects were assessed by repeated measure two-way ANOVA (time x group). When a significant F value was achieved across time or between groups, Bonferroni post hoc procedures were performed to locate the pairwise difference between the mean values. In the case of differences between groups at baseline, a paired t-test was used to compare pre and post values within groups. An ANCOVA was applied with post-training values as the dependent variable and pre-training values as the covariate (12, 18). Effect size magnitude was set according to Rhea (2004). An alpha level less than 0.05 ($p < 0.05$) was considered significant for all analysis, and all were carried out with SPSS version 18.0 (SPSS Inc., Chicago).

RESULTS

Absolute and relative 1-RM values are presented in Table 1. There was no difference between groups at baseline ($p > 0.05$). Both groups increased absolute and relative 45º leg press 1-RM ($p < 0.05$), and absolute bench press 1-RM ($p < 0.05$), while only VHS-RT increased relative bench press 1-RM (p < 0.01). Although no significant time x group interactions were observed for relative and absolute 45º leg press and bench press 1-RM (p > 0.05), VHS-RT displayed greater effect sizes for relative, and absolute 1-RM than HS-RT (Table 1).

Table 1. Absolute and relative muscle strength

	LP Pre (kg)	LP Post (kg)	ES	BP Pre (kg)	BP Post (kg)	ES	LP RMS Pre-	LP RMS Post	ES	BP RMS Pre	BP RMS Post	ES
VHS	120.00 ± 29.15	170.00 ± 53.62*	1.71 (M)	22.06 ± 2.98	27.32 ± 4.96*	1.77 (M)	1.88 ± 0.44	2.76 ± 0.89*	2.01 (L)	0.35 ± 0.05	0.44 ± 0.09*	2.02 (L)
HS	103.82 ± 31.51	134.27 ± 35.60*	0.97 (S)	24.09 ± 4.50	26.91 ± 4.72*	0.63 (S)	1.49 ± 0.44	1.93 ± 0.54*	1.01 (S)	0.35 ± 0.05	0.39 ± 0.07	0.98 (M)

Data are expressed as means and SD. VHS = Very High supervision ratio group (2:1). HS = High supervision ratio group (5:1). ES = Effect size. RMS = Relative muscle strength. BP = Bench Press. LP = Leg Press. S = Small. M = Moderate. L = Large. * = Greater than pre-training values (p < 0.05).

Results for the TUG and six-minute walk tests are reported in table 2. At baseline, TUG was different between groups (p > 0.05). Only VHS-RT increased TUG performance (p = 0.01), while HS-RT showed a close significant F value (p = 0.05). Moreover, ANCOVA revealed no difference in post-values between groups when pre-test values were used as a covariate (p = 0.20). Both groups reported small effect sizes. There was no change in the six-minute walk test performance, regardless of supervision ratio (p = 0.74).

Table 2. Functional capacity

	TUG - Pre-Training (s)	TUG - Post-Training (s)	Effect Size	6min - Pre-Training (m)	6min - Post-Training (m)	Effect Size
VHS	5.84 ± 0.54#	5.36 ± 0.90*	- 0.89 (S)	559.44 ± 45.72	560.00 ± 45.55	0.01 (T)
HS	6.85 ± 0.83	6.35 ± 0.84	- 0.61 (S)	524.05 ± 38.49	516.41 ± 72.31	- 0.20 (T)

Data are expressed by means and SD. VHS = Very High supervision ratio group (2:1). HS = High supervision ratio group (5:1). TUG = Time up and go test. 6min = six minute walk test. T = Trivial. S = Small. # = Lower than HS-RT at pre-training (p < 0.05).* = Lower than pre-training values (p < 0.05).

Body composition and effect sizes are shown in table 3. At baseline, only lean mass differed between groups. There was no change in body weight (p > 0.05). A significant interaction (group x time) was observed for fat mass (p = 0.02), and close significant F value (p = 0.07) for fat mass percentage. Only VHS-RT displayed a significant decrease in fat mass (p = 0.01) and fat mass percentage (p = 0.01), while no change was detected in HS-RT (p > 0.05). No significant improvements in lean mass were observed for either group (p > 0.05). Bone mineral content significantly increased with training (p = 0.04) for VHS-RT (p = 0.04), with no significant improvements for HS-RT (p = 0.99).

Table 3. Body composition

	BW Pre (kg)	BW Post (kg)	ES	RFM Pre (%)	RFM Post (%)	ES	FM Pre (kg)	FM - Post (kg)	ES	LM Pre (kg)	LM Post (kg)	ES	BM Pre (kg)	BM Post (kg)	ES
VHS	64.06 ± 6.99	62.55 ± 9.34	- 0.22 (T)	43.38 ± 6.12	41.77 ± 6.10δ	- 0.26 (T)	26.94 ± 6.72	25.43 ± 6.64δ	- 0.22 (T)	34.15 ± 2.11$^{\#}$	34.60 ± 2.09	0.21 (T)	1.99 ± 0.12	2.08 ± 0.22*	0.69 (S)
HS	70.44 ± 12.19	70.84 ± 12.57	0.03 (T)	43.36 ± 8.59	42.99 ± 9.37	- 0.04 (T)	30.21 ± 9.31	30.21 ± 10.03	0.00 (T)	37.84 ± 3.80	38.05 ± 3.57	0.06 (T)	2.11 ± 0.30	2.13 ± 0.34	(0.05 (T)

Data are expressed as means and SD. VHS = Very High supervision ratio group (2:1). HS = High supervision ratio group (5:1). BW = Body Weight. RFM = Relative Fat Mass. FM = Fat mass. LM = Lean Mass. BMC = Bone mineral content. T = Trivial. S = Small. ES = Effect size. $^{\#}$ = Lower than HS-RT at pre-training ($p < 0.05$). * = Greater than pre-training values ($p < 0.05$). δ = Lower than pre-training values ($p < 0.05$).

Irisin and BDNF were not different between groups at baseline ($p > 0.05$). Irisin did not change with RT ($p > 0.05$). BDNF increased in HS-RT ($p = 0.01$), but not VHS-RT ($p = 0.63$). Effect sizes are shown in Table 4.

Table 4. Brain derived neurotrophic-factors and irisin

	BNDF - Pre-Training (pg/mL)	BNDF - Post-Training (pg/mL)	Effect Size	Irisin - Pre-Training (ng/mL)	Irisin - Post-Training (ng/mL)	Effect Size
VHS	1734.85 ± 317.83	1758.56 ± 321.13	- 0.08 (T)	196.94 ± 57.12	196.35 ± 97.17	- 0.01 (T)
HS	1549.44 ± 84.43	1642.31 ± 87.23*	1.10 (M)	205.27 ± 53.02	206.74 ± 61.64	0.03 (T)

Data are expressed by means and SD. VHS = Very High supervision ratio group (2:1). HS = High supervision ratio group (5:1). BNDF = Brain derived neurotrophic-factor. T = Trivial. M = Moderate. * = Greater than pre-training values ($p < 0.05$).

DISCUSSION

The main finding of this study was that RT increased muscle strength independent of supervision ratio in elderly subjects. A greater supervision ratio during RT resulted in more pronounced improvements in muscle strength, demonstrated by greater effect sizes in VH-RT compared to HS-RT. Improvements in fat mass and fat mass percentage were restricted to very high supervision ratio, confirming the initial hypothesis. Finally, only HS-RT increased BDNF.

The influence of RT-supervision in muscle function has been classically demonstrated in the literature (20). In this regard, supervised RT promotes improvements in muscle function to a greater extent than non-supervised RT (18). However, the supervision ratio may influence RT-induced improvements in muscle function (12, 23). In fact, high supervision during RT (i.e. a 1:5 ratio of supervisors/exercisers) showed better improvements in muscle strength than low supervision ratio in young subjects (i.e. vs a 1:25 ratio of supervisors/exercisers). In addition, supervised high-speed RT (i.e. 1:1 supervisor/exerciser) in elderly subjects has been demonstrated to better improve muscle strength and functional performance than low supervised high-speed RT (1:10 supervisors/exercisers) (23).

In addition to the aforementioned issues, the current study reported a greater increase in muscle strength in VHS-RT compared to HS-RT. Thus, these results may suggest that even in high-supervised RT (i.e. lower than five exercisers per supervisor) a greater supervision ratio induces better improvements in muscle strength. In this regard, greater supervision may permit a closer presence of coaches to exercisers during RT. Greater verbal and expert instruction regarding exercise technique and muscle emphasis required for each exercise may increase muscle activity during exercise (29, 30). Moreover, daily undulating RT requires day-to-day load adjustments (20, 21). Therefore, a closer presence of coaches also could help exercisers to have improved load adjustments and increments during the RT program, as muscle activity during exercise and training load are associated with muscle strength improvements (5, 27). Thus, it would be expected that a high supervision ratio during RT could induce greater muscle strength improvements than low supervision ratio, as reported in the current study.

Although only VHS-RT significantly improved TUG performance, HS-RT showed an F value close to statistical significance ($p = 0.05$). Furthermore, both groups demonstrated small effect sizes and similar pre-post differences (9.0% and 8.7% for VHS-RT and HS-RT, respectively). Enhanced TUG performance is usually occasioned by an increase in muscle power (14). In this regard, Ramírez-Campillo et al. (23) showed improvements in muscle power in high supervised compared to low supervised high-speed RT. In contrast, Mazzetti et al. (18) did not report differences in muscle power enhancements between supervised and non-supervised traditional RT. Therefore, considering the aforementioned issues and the current study, it may be suggested that supervision ratio influences muscle power improvements and consequently TUG performance in high-speed RT, but not in traditional RT.

The fat mass and fat mass percentage improved only in VHS-RT. In addition, no significant enhancements in lean mass were found in both groups. Althougth only VHS-RT reduced fat mass, exercise is not the sole factor involved in body composition adaptations (3). In this regard, Bouchard et al. (3) reported that RT only reduced fat mass when accompanied by caloric restriction. Moreover, Esmarck et al. (9) showed that lean mass increased when RT is followed by protein supplementation, but it reduced when a fasting period succeed the RT. Therefore, considering the aforementioned studies, it may be implied that the adequate nutrition also contributes to fat mass and lean mass adaptations. Since caloric intake was not controlled in the current study, we cannot attribute these body composition adaptations in the VHS-RT only to the supervision ratio (3, 7).

RT enhances bone mineral content in elderly subjects (13). However, in the current study, only VHS-RT increased BMC. Several factors are associated with BMC, such as fat mass and muscle strength (28). Thus, it might be possible that improvement in BMC is not related directly with the supervision ratio but related to improvements in muscle strength and fat mass resulting from RT. Indeed, VHS-RT showed a greater improvement in muscle strength and fat mass than HS-RT. In addition, an important biomarker associated with bone health is irisin (2). Although evidence suggests that irisin is stimulated by physical exercise (16), our RT protocol did not change irisin concentrations, independent of supervision ratio. In contrast to the current study, Kim et al. (17) reported an increase in serum irisin after eight weeks of RT (five times per week).

However, similar to the current study Prestes et al. (20) reported that linear and undulating periodized RT two times per week did not change serum irisin concentrations in elderly subjects. Thus, the impact of RT in serum irisin concentrations remains unclear.

In contrast to our hypothesis, only the HS-RT improved BDNF. However, the influence of RT on serum BDNF remains unclear (8, 11). Since BDNF may show an individual responsiveness to RT (20), the results of the current study may not be attributed to training supervision or training variations. Indeed, in the current study 56% of VHS-RT participants were low responders, while 78% of HS-RT participants were high responders. Considering these differences, individual responsiveness of BNDF to the RT must be considered to avoid inaccurate interpretation of this research.

It is important to note that there are some limitations in the current study, such as no presence of a control group, which could help to elicit the positive and negative effects of exercises compared to sedentary subjects. Moreover, the absence of overall weight load carried out in each session per individual, which could help to determine whether the intensity was higher in VHS-RT. In addition, since a previous study reported that undulating periodization RT twice a week did not change irisin concentrations (20), the RT frequency or periodization may be insufficient to improve irisin concentrations.

In summary, RT independent supervision ratios induced improvements in functional capacity and muscle strength. However, VHS-RT could lead to greater enhancements in muscle strength than HS-RT. Additionally, only VHS-RT improved body composition. Although HS-RT increases BDNF, this result must be interpreted with caution, due to individual responsiveness.

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