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High and Low-speed Resistance Training Induce Similar Physical and Functional Responses in Older Women

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ABSTRACT

International Journal of Exercise Science 15(4): 771-782, 2022. This study aimed to compare the effects of high-speed resistance training (HSRT) and low-speed resistance training (LSRT) in physical fitness, and functional performance in untrained older women. Twenty-four women (62.2 ± 2.7 years old) were allocated to the HSRT or LSRT groups. The HSRT and LSRT groups underwent a similar training program [3 sets of 8 to 12 repetitions at 90% of 10 maximum repetitions] for 14 weeks, twice a week. The LSRT group performed the exercises with 3 seconds in the concentric and eccentric phases, while the HSRT group performed with the concentric phase as quickly as possible and 3 seconds in the eccentric phase. Participants completed pre-and post-training testing to assess strength, flexibility, muscle endurance, power, walking speed, functional balance, and aerobic endurance. Two-way mixed-model ANOVA with repeated measures was applied for each variable, and the Bonferroni post hoc was used when necessary. Statistical significance was set at $p < 0.05$. No significant group*time interactions were found for any variable. Time main-effect suggested significant improvements for the 10 RM bench press ($F = 46.1$; $p < 0.001$), 10 RM leg press ($F = 49.8$; $p < 0.001$), sit-to-stand test ($F = 10.4$; $p = 0.004$), sit and reach ($F = 10.5$; $p = 0.004$), Timed Up-and-Go ($F = 29.8$; $p < 0.001$) and 6-min walking test ($F = 41.6$; $p < 0.001$). Thus, the configurations of RT tested here were similarly efficient to improve the functional performance of untrained older women. In addition, both groups showed significant gains in muscle strength, but not in muscle power and gait speed.

KEY WORDS: Ageing, strength training, exercise

INTRODUCTION

Resistance training (RT) has been highly recommended as an important component in physical activity programs for older adults (46) due to its effects on functional independence, longevity, and quality of life (24). Those effects are mainly related to the efficiency of this training model for muscle strength and power development, muscle mass maintenance, and cognitive processing (17). However, the efficacy of RT programs is dependent on specific training variables that can be manipulated. For example, exercise load, volume, frequency, range of

motion, recovery time between sets and exercises, and movement speed are variables often manipulated (2).
Regarding movement speed, previous studies suggest that both high-speed (HSRT) and low-speed resistance training (LSRT) are effective for inducing muscle strength gains in older adults (4, 15, 23, 39). Ramirez-Campillo et al. (31) compared HSRT versus LSRT in older women and found relevant improvements in functional capacity, muscle performance, and quality of life for both groups, however, responses after HSRT were more prominent. In a recent debate, Cadore et al. (9) questioned the recommendations that contraction speed for older adults should be controlled at a rate between 2-4 seconds, avoiding explosive movements (16). In summary, the authors (9) argue that HSRT is viable for this population and is associated with improvements in daily activities and functional abilities, mainly due to its relationship to energy production and the rate of force development.

On the other hand, suggestions to raise training loads seem also interesting for this population and would be related to higher effort and/or higher external load (21). Besides, when high-load RT is performed, the higher loads seem not to impair muscle power gains (44) and a lower training volume should be used, which is in turn related to improvements in lower limb muscle power (42). However, the fatigue associated with RT taken to momentary muscle failure could reduce power output along with the sets (22). Thus, one remaining question is concerning the role of the speed of concentric contractions on functional performance and strength improvements when high-intensity RT (high-load and low velocity) is performed.

In this context, considering the complexity of RT prescription and its importance for the older adults population (8), it became relevant to investigate the effects of high-load RT at different speeds of concentric contractions on muscle strength and power, and functional abilities. Therefore, this study aimed to compare the effects of HSRT and LSRT on physical fitness, and functional performance in previously untrained older women.

METHODS

Participants
For sample size estimation the G*power package was used considering two groups, two repeated measures, and correlation among repeated measures of 0.5. To reach 0.95 statistical power, and medium F effect sizes (0.75) a sample of 20 participants would be needed. Forty-five untrained older women were recruited for this study. Inclusion criteria were not having any condition that impaired performance in the proposed tests, being aged ≥ 60 years old, have not performed any type of RT for at least three months before the intervention. The exclusion criteria were: not performing ≥ 80% of all training sessions (≥ 22 out of 28 sessions) and not attending pre and post-assessments (19). At the end of the experiment, twenty-four participants (62.2 ± 2.7 years old, 1.68 ± 1.7 cm of height, and 65.5 ± 7.5 kg of body mass) were included in the final analysis. The study procedures were approved by the Ethics and Research Committee of the Institute of Science and Health from the Federal University of Pará following the Declaration of Helsinki. This research was carried out fully by ethical standards of the International Journal of

Exercise Science (28) and reporting in this article is aligned with Consolidated Standards of Reporting Trials (CONSORT).

Protocol

Initially, the participants signed an informed consent form and performed the anthropometric assessments. Before data collection, the participants underwent two weeks of RT familiarization [2 sets of 15 repetitions, with comfortable and self-selected load], in which the participants were instructed to perform the exercises correctly. At the end of familiarization, the subjects performed a 10-repetition maximum test (10 RM). After 48 hours, the participants performed, in a circuit form, the following tests: sit-and-reach test, countermovement jump (CMJ) and squat jump (SJ), timed up-and-go test (TUG), 10-meter walking speed, sit-to-stand test, arm curl, and 6-minute walking test. All tests were performed with an interval of 5 minutes between them. Data collection was performed before the intervention and after 14 weeks of training. Both protocols maintained a frequency of two days per week. To generate a counterbalanced allocation, a simple draw was made considering the performance in the leg press 10RM test. Randomization occurred as follows: After the results of the 10RM test, the data were organized in decreasing order. The groups (HRST and LSRT) were randomized (https://www.random.org/) to start the distribution. Participants with the same results were also randomized to the order of distribution. After that, the subjects were allocated to each group, in a counterbalanced way. Also, the training supervisors who followed the RT sessions were randomized and distributed on work scales, also by simple draw, so that they gave the same number of sessions for each group. All procedures had direct guidance from instructors with high experience in the prescription of the tests applied in this research. All the coordinators responsible for applying the training methods had previous experience in RT. In addition, a ratio of 1 evaluator for every 3 participants was maintained to avoid bias in the RT prescription, data collection, and decrease the probability of injuries during the procedures. Finally, the participants were advised to keep the same dietary habits during the entire intervention period.

Anthropometric Indicators: For anthropometric indicators, body mass, height, and waist circumference were evaluated. The assessment of body mass was performed using a digital scale (G - Tech Balgl10, DayHome Comercial LTDA, Brasil). To measure height, a manual measuring tape (Western®) fixed on the wall was used. Waist circumference was measured using an inextensible measuring tape (FM-150 Balmak) at the midpoint between the upper anterior iliac crest and the last rib, with an accuracy of 0.1 cm (36). All participants were wearing light clothes and without shoes. All the measures present high values of reproducibility (ICC = 0.95).

Countermovement and Squat Jumps: A contact mat (Jump System Pro® Contact Mat CEFISE, Nova Odessa, Brazil) was used to measure lower limb power. The CMJ consisted of the simultaneous flexion of the knees, hips, torso, and ankle, and subsequently jump upwards to achieve the highest possible height, without performing knee flexion in the flight phase and landing contact with the landing. The participants were asked to perform three attempts, the best jump, and the average of the three jumps was considered in the analysis. The SJ consisted of a static squat position, with the knees at 90º flexion, then extending the lower limb to jump as vertically as possible (27). The test has a reported intraclass correlation coefficient (ICC) value between 0.88 to 0.99 (34) for mixed adult and older adults populations and an intra-class correlation of 0.91 specifically for older women (14).

Functional tests: The battery of tests that were used to assess functional capacity includes assessments of upper and lower body strength, aerobic resistance, agility, dynamic balance, and upper and lower body flexibility (36). Participants were instructed on the proper technique for carrying out the tests before the start and during the evaluations. In addition, participants were encouraged to give maximum effort in all tests.

Sit-to-stand test: First, the participants positioned themselves standing in front of a chair without the support and were instructed to cross their arms to avoid upper limb effects in the test performance. Subsequently, they were instructed to sit in the chair (~90º of knee flexion), then immediately returned to the starting position, all participants were verbally encouraged to perform as many repetitions as possible within 30 seconds (45).

Arm curl: Participants performed complete elbow flexion and extension with the supine grip using 5lb dumbbells as resistance and performing the maximum number of repetitions for 30 seconds. The test was performed with the participant in a seated position (1).

Sit-and-Reach test: Participants performed the test in a sitting position in front of a chair, with one leg extended and the hands reaching the toes, the distance between the extended fingers and the top of the toe was recorded in cm (26).

10-m walking speed: The walking speed was assessed at a distance of 10 m. Participants took the test twice and the arithmetic mean of the two tests was used for scoring purposes. The subjects were instructed to walk starting with the dominant foot as quickly as possible and continue until the end of a marked path (29). Time was measured using a portable stopwatch. The results showed high reliability (ICC > 0.96).

6-minute walking test: This test was performed as previously described (1). Participants were instructed to walk along a 30m trail as quickly as possible for six minutes. Participants could rest during the test, if necessary, but were instructed to continue walking as quickly as possible.

Timed Up-and-Go (TUG): The TUG test begins with the participant sitting in the chair and when asked the evaluated raises and walks three meters, returning to the initial position (sitting). Two attempts were performed, and the shortest time was considered in the analysis. Time was measured in seconds (37). The older women performed the test by walking at a fast pace.

Repetition maximum test (10RM): Before and after 14 weeks of the intervention, participants performed 10RM tests on the bench press and leg press. The tests were performed on the same day. The 10RM was chosen over the 1RM because when participants are training at high repetition ranges, it seems more appropriate to evaluate performance through multiple

repetition tests (5). Before the tests, the participants warmed up with 10 reps at a comfortable self-selected load and then rested for 5 min. Then the initial load was defined based on the participant's training history. If the volunteer could not perform 10 repetitions or performed more than 10 repetitions, the load was adjusted by 1–10 kg, and another attempt was performed after 5 min of rest. No more than three attempts were necessary for any occasion.
Training protocols: Training sessions were performed twice a week, for 14 weeks, with a period of recovery of 48 hours between sessions. All participants performed a full-body protocol, composed of three exercises for upper limbs (bench press, seated row, military press) and three for lower limbs (leg press, deadlift, calf raise) following a minimal dose approach (Table 1) (16). The choice of these multi-joint exercises was based on previous suggestions (20). In the week before the start of the study, participants were familiarized with exercises and equipment. Each exercise was performed with three sets, with 8-12 RM, defined as the point of volitional muscle failure under the previous definition (40). Sixty seconds of rest intervals were used between sets and exercises. The training load started at 90% 10RM. Each time that participants performed the sets at the upper limit of repetitions, there was a load increase (5% to 10%) in the next session. All exercise sessions were supervised by an experienced strength training specialist (Ph.D.) and physical education graduate students at a supervision ratio of 1 supervisor per 3 volunteers (18). The only difference between the groups was the execution of the exercises, in which the LSRT group performed the exercises with 3 seconds in the concentric and eccentric phase, while the HSRT group performed with the concentric phase as fast as possible and 3 seconds in the eccentric phase. The control of concentric phase duration was closely monitored by the supervisors, and verbal instructions were made when needed. The duration of the training sessions was approximately 1 hour.

Table 1. Description of the RT program.

Exercises	Sets x Reps	Starting external load (%10RM)
Bench Press	3 x 8-12	90%
Seated Row	3 x 8-12	90%
Military Press	3 x 8-12	90%
Leg press	3 x 8-12	90%
Deadlift	3 x 8-12	90%
Calf Raise	3 x 8-12	90%

Statistical Analysis

After the Shapiro-Wilk's normality test for normality, data is presented by the mean and standard deviation. Two-way mixed-model ANOVA was performed considering groups (HSRT vs LSRT) and data collection time-points (pre vs post). If a significant interaction were reached, the Bonferroni post hoc test would be applied. Effect sizes were presented by Cohen's d_z, as previously suggested (13, 25). The magnitude of Cohen's d_z effect sizes was scaled as trivial (< 0.50), small (0.50 to 1.25), moderate (1.25 to 1.9), and large (> 2.0), according to definitions for strength training research with untrained participants (33). The analysis was performed using the statistical package SPSS 20.0. The level of significance adopted to all tests was $p < 0.05$.

RESULTS

The CONSORT diagram is presented in Figure 1. All participants signed an informed consent form at the enrollment phase. Of the forty-five women enrolled, two were excluded due to lumbar and cervical joint disorders, one due to the diagnosis of knee arthrosis, and five participants did not attend the baseline tests. Therefore, thirty- seven women were including and randomly assigned to the HRST (*n* = 18) and LSRT (*n* = 19) groups. However, in the HRST group, after allocation, one participant did not remain in the survey due to difficulty in getting to the training site, three women did not perform ≥ 80% of all training sessions due to "method adherence" or "lack of motivation" and two participants were excluded from the final analysis because they had incomplete data. In the LSRT group, one was excluded due to a wrist fracture after suffering a fall, one woman was withdrawn from the survey because she was absent for an emergency trip, four did not perform ≥ 80% of all training sessions due to "method adherence" or "lack of motivation" and one participant were excluded from the final analysis because they had incomplete data.

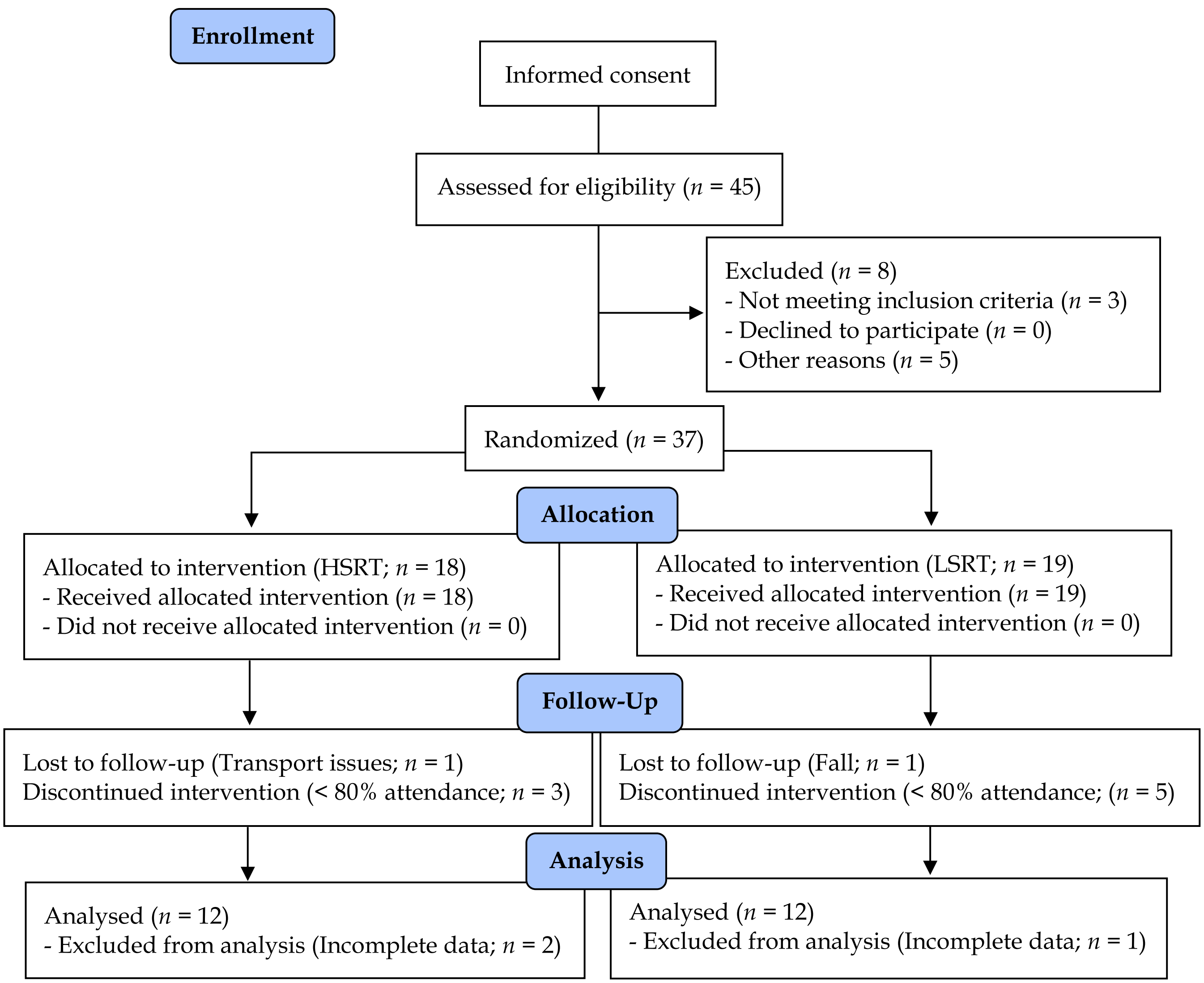

Figure 1. Enrolment and allocation flow diagram, as suggested by CONSORT.

Table 2 presents comparisons between collection time-point and groups for anthropometric and physical responses to HSRT and LSRT. No time*groups interactions were found for any variable. Regarding main effects, waist circumference ($F = 16.4$; $p = 0.001$), bench press ($F = 46.1$; $p < 0.001$), leg press ($F = 49.8$; $p < 0.001$), sit-to-stand test ($F = 10.4$; $p = 0.004$), sit and reach ($F = 10.5$; $p = 0.004$), TUG ($F = 29.8$; $p < 0.001$) and 6-min walking test ($F = 41.6$; $p < 0.001$) responded positively for time analysis (Table 2). No between-groups main effects were found for body mass ($F = 0.1$, $p = 0.716$), waist circumference ($F = 0.1$; $p = 0.669$), 10 RM bench press ($F = 0.5$; $p = 0.482$), 10 RM leg press ($F = 0.2$; $p = 0.648$), CMJ ($F = 0.3$; $p = 0.534$), SJ ($F = 1.0$; $p = 0.326$), sit-to-stand test ($F = 0.1$; $p = 0.731$), elbow flexion ($F = 1.1$; $p = 0.288$), sit and reach ($F = 0.3$; $p = 0.572$), TUG ($F = 0.02$; $p = 0.500$), 10m walking speed ($F = 0.1$; $p = 0.798$) and 6-min walking test ($F = 0.4$; $p = 0.505$).

Table 2. Mean and standard deviation from anthropometric and physical responses to high and low-speed resistance training programs.

	HSRT		LSRT		Group*time interaction		
	Pre	Post	Pre	Post	*F*	η^2	*p*
Body mass (kg)	66.2 ± 10.5	66.1 ± 11.8	64.4 ± 8.7	64.4 ± 8.6	0.6	0.03	0.413
Waist circumference (cm)	91.3 ± 7.5	88.8 ± 7.6	91.3 ± 7.3	86.3 ± 7.2	0.9	0.08	0.181
10 RM bench Press (kg)	11.0 ± 6.4	16.3 ± 5.6	12.3 ± 3.9	17.7 ± 3.4	0.0	0.00	1.000
10 RM leg press (kg)	94.2 ± 43.8	122.5 ± 29.9	97.5 ± 24.5	130.0 ± 18.1	0.2	0.01	0.633
CMJ (cm)	10.7 ± 4.0	10.8 ± 3.8	11.5 ± 3.4	11.9 ± 3.3	0.2	0.01	0.590
SJ (cm)	10.4 ± 4.2	10.9 ± 3.4	11.8 ± 2.8	12.3 ± 3.3	0.0	0.00	0.903
Sit-to-stand (reps)	17.6 ± 4.2	19.7 ± 3.5	17.2 ± 2.8	19.3 ± 2.6	0.0	0.00	1.000
Arm curl (reps)	23.0 ± 3.5	24.0 ± 4.6	24.3 ± 2.7	25.4 ± 3.2	0.0	0.00	0.954
Sit and reach (cm)	29.6 ± 7.3	31.6 ± 7.4	28.0 ± 7.1	29.9 ± 7.2	0.0	0.00	0.889
TUG (s)	6.0 ± 0.7	5.2 ± 0.8	5.9 ± 0.7	5.5 ± 0.6	3.3	0.13	0.080
10-m walking speed (s)	3.6 ± 0.5	3.5 ± 0.8	3.5 ± 0.8	3.5 ± 0.6	0.2	0.01	0.616
6-min walking (m)	541.8 ± 62.0	634.6 ± 60.7	533.3 ± 89.5	609.6 ± 56.6	0.3	0.01	0.536

HSRT: High-speed resistance training; LSRT: Low-speed resistance training; CMJ: Countermovement Jump; SJ: Squat Jump; RM: Repetition Maximum; TUG: Timed Up-and-Go.

DISCUSSION

The present study aimed to compare the effects of HSRT and LSRT on physical fitness, and functional performance in untrained older women. Overall, the findings suggest that RT performed with different speeds of concentric contraction promotes a similar increase in strength, aerobic endurance, functional balance, and a similar reduction in waist circumference in untrained older women.

Muscle strength reduction due to aging increases the functional dependence of the older adults (38), causing the reduction of physical activity levels and, consequently, worsening the degree of strength and functionality (8). RT programs are well established as the main strategy to counter the strength losses expected from aging (0.8 to 3.6% per year), since expected strength improvements would range from 9 to 174%, according to a recent position stand (17). Although it has been previously demonstrated, our results provide additional evidence that 14 weeks of both HSRT and LSRT promoted ~30% and 40% of strength gains in lower and upper body segments, respectively. The absence of differences between protocols was probably related to the similar high-load approach used for both groups since both were performed to volitional momentary failure and at loads that would be correspondent to ~75% 1RM (35,41,43). Thus, performing RT to volitional fatigue may cause a standardization effect which leads to similar responses to RT, independently of the concentric contraction speeds used (12).

It is important to highlight that this high-load characteristic is the reason why the improvements in muscle strength were reached with a training volume lower than usually recommended for older adults (6 sets a week per muscle group) (17). Our findings support the notion that high-load efforts should not be avoided in this population and are not necessarily a synonym of injury, adverse symptoms, or drop-outs (21). In summary, our results are in agreement with several studies that found that, regardless of age, both training speeds are recommended and effective for muscle strength gains (11, 23, 39).

As high-load efforts, high-speed contractions should also not be avoided in RT for older adults (9). The rationality for this statement is based on the notion that muscle power improvements would be optimized when high-speed concentric actions are performed (9, 17). Based on that, and in the notion that the training volume is inversely related to muscle power gains (42), we proposed our experimental model. However, it seems that some choices we made could explain why neither HSRT and LSRT induce improvements in vertical jumps performance and gait speed. First, the use of high-load efforts near muscle failure can reduce the power output produced across the set. In addition, the short inter-sets rest may have limited energetic and muscle power re-establishment (22). Second, the range of loads applied (~75%1RM) was higher than the 30 to 60%1RM that is usually recommended for power output maintenance along with an RT session (7). Despite that, the load we chose is in accordance with the recommendations (50-80% 1RM) for power training programs, even though this choice may compromise the actual speed of movement (6). In this sense, the inclusion of lower-load sets would be of interest for older adults, as shown by Ramirez-Campillo et al., (30), which evidenced improvements in muscle power in older women with crescent loads (from 45%, 60%, to 75% 1RM) in each set. In summary, our findings support the idea that improvements in muscle power may not be optimized when higher loads are applied, regardless of the intention to perform high-speed concentric actions, which reinforces recommendations for the addition of specific power training with varying loads for this population.

Regarding the functional performance, the sit-to-stand test, sit and reach test, TUG test, and 6-min walking test level improved similarly in both groups. A previous investigation suggested that a high-load LSRT program (3 sets of 7 reps at 80%1RM) was more beneficial than low-load HSRT (3 sets of 14 reps at 40%1RM) to improve functional performance (35). The authors suggested that their findings could be explained by the higher load and intensity of effort in the high-load LSRT protocol. This is in opposition to a meta-analysis which indicated that, despite there being a small-to-moderate advantage for power training with fast contractions over traditional RT methods, lower loads would be more related to functional performance and muscle power while higher loads would be more efficient for strength (6). Otherwise, the authors recognized that the use of a variety of loads would be of interest in power training RT programs. Another meta-analysis also evidenced that power training would have a greater impact on chair rise ability (sit-to-stand test), but not necessarily for the timed-up-and-go and the walking speed tests. Regarding our results, we speculate that the strength gains could partially explain improvements in the timed-up-and-go test and 6-min walking test, due to the role of strength in the change of direction ability and walking economy, respectively. On the other hand, the absence of effect in walking speed may be explained by the starting fitness level of participants since the mean speed achieved was 171.4 cm/s in baseline, which is higher than the expected for women between 60 and 69 years old (124.1 cm/s) (3).

In summary, our results demonstrate that both RT protocols were efficient to improve the functional performance of untrained older women. Additionally, both groups demonstrated significant gains in muscle strength but not in muscle power and gait speed. Thus, high-load RT protocols that use high-speed or low-speed in the concentric phase are important tools for RT prescription for older women. For the proper interpretations of our findings, some limitations need to be addressed. First, the actual speed of concentric actions was not objectively measured, however, the supervisor, the subject ratio was planned to provide sufficient control and monitoring. Supervisors continuously provided the stimulus to encourage the intended "as fast as possible" speed. The reduced internal validity of some of the physical tests is another limitation, however, these tests are widely applied in research about exercise for older adults and had an elevated external validity and practical application in the field.

Practical applications: Our findings seem to support the main recommendations about RT for older adults (10, 17, 32) stating that high-load training with high levels of effort brings relevant and desired changes in physical fitness and functional parameters regardless of the speed of concentric contractions. It's speculated that lower and high speeds of concentric contraction cause similar responses in the physical capacity of untrained older women. However, the addition of specific functional exercises at different ranges of loads should be considered, since the intention to perform fast repetitions maybe is not enough to guarantee lower-limbs power improvements. It is our opinion that, when considering our data in the light of the scientific literature on this topic, trainers, coaches, and health care professionals should be encouraged to prescribe RT programs for older adults. Specifically, we provide more evidence that low-volume and high-load RT programs are safe and effective in this population and, in this case, regardless of the intention to do it faster.

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REFERENCES

1. Barbalho M de SM, Gentil P, Izquierdo M, Fisher J, Steele J, Raiol R de A. There are no no-responders to low or high resistance training volumes among older women. Exp Gerontol 99: 18–26, 2017.

2. Bird SP, Tarpenning KM, Marino FE. Designing resistance training programmes to enhance muscular fitness. Sports Med 35(10): 841–51, 2005.

3. Bohannon RW, Williams Andrews A. Normal walking speed: A descriptive meta-analysis. Physiotherapy 97(3): 182–9, 2011.

4. Bottaro M, Machado SN, Nogueira W, Scales R, Veloso J. Effect of high versus low-velocity resistance training on muscular fitness and functional performance in older men. Eur J Appl Physiol 99(3): 257–64, 2007.

5. Buckner SL, Jessee MB, Mattocks KT, Mouser JG, Counts BR, Dankel SJ, et al. Determining strength : A case for multiple methods of measurement. Sports Med 47(2): 193–5, 2016.

6. Byrne C, Faure C, Keene DJ, Lamb SE. Ageing, muscle power and physical function: A systematic review and implications for pragmatic training interventions. Sports Med 46(9): 1311–32, 2017.

7. Cadore EL, Izquierdo M. Muscle power training: A hallmark for muscle function retaining in frail clinical setting. J Am Med Dir Assoc 19(3): 190-2, 2018.

8. Cadore EL, Moneo ABB, Mensat MM, Muñoz AR, Casas-Herrero A, Rodriguez-Mañas L, et al. Positive effects of resistance training in frail elderly patients with dementia after long-term physical restraint. Age (Omaha) 36(2): 801–11, 2014.

9. Cadore EL, Pinto RS, Reischak-Oliveira Á, Izquierdo M. Explosive type of contractions should not be avoided during resistance training in elderly. Exp Gerontol 102(October 2017): 81–3, 2018.

10. Chodzko-Zajko WJ, Proctor DN, Fiatarone Singh MA, Minson CT, Nigg CR, Salem GJ, et al. Exercise and physical activity for older adults. Med Sci Sports Exerc 41(7): 1510–30, 2009.

11. Claflin DR, Larkin LM, Cederna PS, Horowitz JF, Alexander NB, Cole NM, et al. Effects of high- and low-velocity resistance training on the contractile properties of skeletal muscle fibers from young and older humans. J Appl Physiol 111(4): 1021–30, 2011.

12. Dankel SJ, Jessee MB, Mattocks KT, Mouser JG, Counts BR, Buckner SL, et al. Training to fatigue: The answer for standardization when assessing muscle hypertrophy? Sports Med 47(6): 1021–7, 2017.

13. Dankel SJ, Loenneke JP. Effect sizes for paired data should use the change score variability rather than the pre-test variability. J Strength Cond Res 35(6): 1773-8, 2021.

14. Farias DL, Teixeira TG, Madrid B, Pinho D, Boullosa DA, Prestes J. Reliability of vertical jump performance evaluated with contact mat in elderly women. Clin Physiol Funct Imaging 33(4): 288–92, 2013.

15. Fielding RA, LeBrasseur NK, Cuoco A, Bean J, Mizer K, Fiatarone Singh MA. High-velocity resistance training increases skeletal muscle peak power in older women. J Am Geriatr Soc 50(4): 655–62, 2002.

16. Fisher JP, Steele J, Gentil P, Giessing J, Westcott WL. A minimal dose approach to resistance training for the older adult: The prophylactic for aging. Exp Gerontol 99: 80–6, 2017.

17. Fragala MS, Cadore EL, Dorgo S, Izquierdo M, Kraemer WJ, Peterson MD, et al. Resistance training for older adults: Position statement from the National Strength and Conditioning Association. J Strength Cond Res 33(8): 2019–52, 2019.

18. Gentil P, Bottaro M. Influence of supervision ratio on muscle adaptations to resistance training in nontrained subjects. J Strength Cond Res 24(3): 639–43, 2010.

19. Gentil P, Bottaro M. Effects of training attendance on muscle strength of young men after 11 weeks of resistance training. Asian J Sports Med 4(2): 101–6, 2013.

20. Gentil P, Fisher J, Steele J. A review of the acute effects and long-term adaptations of single- and multi-joint exercises during resistance training. Sports Med 47(5): 843–55, 2017.

21. Gentil P, Steele J, Fisher J. Why intensity is not a bad word – Benefits and practical aspects of high effort resistance training to the older. Clin Nutr 36(5): 1454–5, 2017.

22. Gorostiaga EM, Navarro-Amézqueta I, Calbet JAL, Hellsten Y, Cusso R, Guerrero M, et al. Energy metabolism during repeated sets of leg press exercise leading to failure or not. PLoS One 7(7): e40621, 2012.

23. Henwood TR, Riek S, Taaffe DR. Strength versus muscle power-specific resistance training in community-dwelling older adults. J Gerontol A Biol Sci Med Sci 63(1): 83–91, 2008.

24. Kraschnewski JL, Sciamanna CN, Poger JM, Rovniak LS, Lehman EB, Cooper AB, et al. Is strength training associated with mortality benefits? A 15 year cohort study of US older adults. Prev Med (Baltim) 87: 121–7, 2016.

25. Lakens D. Calculating and reporting effect sizes to facilitate cumulative science: A practical primer for t-tests and ANOVAs. Front Psychol 4(NOV): 1–12, 2013.

26. Lim J-H, Park C-B, Kim B-G. The effects of vibration foam roller applied to hamstring on the quadriceps electromyography activity and hamstring flexibility. J Exerc Rehabil 15(4): 560–5, 2019.

27. Markovic G, Dizdar D, Jukic I, Cardinale M. Reliability and factorial validity of squat and countermovement jump tests. J Strength Cond Res 18(3): 551–5, 2004.

28. Navalta JW, Stone WJ, Lyons TS. Ethical issues relating to scientific discovery in exercise science. Int J Exerc Sci 12(1): 1-8, 2019.

29. Peters DM, Fritz SL, Krotish DE. Assessing the reliability and validity of a shorter walk test compared with the 10-meter walk test for measurements of gait speed in healthy, older adults. J Geriatr Phys Ther 36(1): 24–30, 2013.

30. Ramirez-campillo R, Alvarez C, Garcìa-hermoso A, Celis-morales C, Ramirez-velez R, Gentil P, et al. High-speed resistance training in elderly women : Effects of cluster training sets on functional performance and quality of life. Exp Gerontol 110(April): 216–22, 2018.

31. Ramírez-Campillo R, Castillo A, Fuente CI De, Campos-jara C, Andrade DC, Álvarez C, et al. High-speed resistance training is more effective than low-speed resistance training to increase functional capacity and muscle performance in older women. Exp Gerontol 58: 51–7, 2014.

32. Ratamess N, Alvar BA, Kraemer WJ. Progression models in resistance training for healthy adults. Med Sci Sports Exerc 41(3): 687–708, 2009.

33. Rhea MR. Determining the magnitude of treatment effects in strength training research through the use of the effect size. J Strength Cond Res 18(4): 918–20, 2004.

34. Rice DP, LaPlante MP. Medical expenditures for disability and disabling comorbidity. Am J Public Health 82(5): 739–41, 1992.

35. Richardson DL, Duncan MJ, Jimenez A, Juris PM, Clarke ND. Effects of movement velocity and training frequency of resistance exercise on functional performance in older adults: A randomised controlled trial. Eur J Sport Sci 19(2): 234–46, 2019.

36. Rikli RE, Jones CJ. Development and validation of criterion-referenced clinically relevant fitness standards for maintaining physical independence in later years. Gerontologist 53(2): 255–67, 2013.

37. Rose DJ, Jones CJ, Lucchese N. Predicting the probability of falls in community-residing older adults using the 8-foot up-and-go: A new measure of functional mobility. J Aging Phys Act 10(4): 466–75, 2002.

38. Roth SM, Ferrell RF, Hurley BF. Strength training for the prevention and treatment of sarcopenia. J Nutr Health Aging 4(3): 143–55, 2000.

39. Sayers SP, Gibson K. A comparison of high-speed power training and traditional slow-speed resistance training in older men and women. J Strength Cond Res 24(12): 3369–80, 2010.

40. Steele J, Fisher J, Giessing J, Gentil P. Clarity in reporting terminology and definitions of set endpoints in resistance training. Muscle Nerve 56(3): 368–74, 2017.

41. Steib S, Schoene D, Pfeifer K. Dose-response relationship of resistance training in older adults: A meta-analysis. Med Sci Sports Exerc 42(5): 902–14, 2010.

42. Straight CR, Lindheimer JB, Brady AO, Dishman RK, Evans EM. Effects of resistance training on lower-extremity muscle power in middle-aged and older adults: A systematic review and meta-analysis of randomized controlled trials. Sports Med 46(3): 353–64, 2016.

43. Teodoro JL, Baroni BM, Gentil P, Cadore EL, Neves LX, Grazioli R, et al. Concurrent training performed with and without repetitions to failure in older men : A randomized clinical trial. Scand J Med Sci Sports 29(8): 1141–52, 2019.

44. De Vos NJ, Singh NA, Ross DA, Stavrinos TM, Orr R, Singh MAF. Optimal load for increasing muscle power during explosive resistance training in older adults. J Gerontol A Biol Sci Med Sci 60(5): 638-47, 2005.

45. Wang H, Wu D, Zhang Y, Wang M, Jiang C, Yang H. The association of physical growth and behavior change with Preschooler's physical fitness: From 10- years of monitoring data. J Exerc Sci Fit 17(3): 113–8, 2019.

46. Zaleski AL, Taylor BA, Panza GA, Wu Y, Pescatello LS, Thompson PD, et al. Coming of age: Considerations in the prescription of exercise for older adults. Methodist Debakey Cardiovasc J 12(2): 98–104, 2016.