Effect of traditional resistance and power training using rated perceived exertion for enhancement of muscle strength, power, and functional performance

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Abstract The present study compared the effects of 12 weeks of traditional resistance training and power training using rated perceived exertion (RPE) to determine training intensity on improvements in strength, muscle power, and ability to perform functional task in older women. Thirty healthy elderly women (60–75 years) were randomly assigned to traditional resistance training group (TRT; $n = 15$) or power training group (PT; $n = 15$). Participants trained twice a week for 12 weeks using six exercises. The training protocol was designed to ascertain that participants exercised at an RPE of 13–18 (on a 6–20 scale). Maximal dynamic

strength, muscle power, and functional performance of lower limb muscles were assessed. Maximal dynamic strength muscle strength leg press ($\approx 58\%$) and knee extension ($\approx 20\%$) increased significantly ($p < 0.001$) and similarly in both groups after training. Muscle power also increased with training ($\approx 27\%$; $p < 0.05$), with no difference between groups. Both groups also improved their functional performance after training period ($\approx 13\%$; $p < 0.001$), with no difference between groups. The present study showed that TRT and PT using RPE scale to control intensity were significantly and similarly effective in improving maximal strength, muscle power, and functional performance of lower limbs in elderly women.

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Introduction

The aging process is characterized by decreases in muscle strength, power, and diminished muscle size and quality (Aagaard et al. 2010; Thompson et al. 2014). These deleterious modifications have a significant impact upon mobility and ability to undertake daily living activities in elderly people (Berger and Doherty 2010). Limitations in mobility, typically defined as difficulty in performing physical tasks, such as walking a one-quarter mile, climbing stairs, or rising from a chair, are indicative of a marked decline in functional health

(Verbrugge and Jette 1994). Although it has been previously showed the importance of strength and muscle size in the lower limbs on mobility and performance activities of daily living, muscle power (the product between muscle force and contraction velocity) is a superior determinant of functional performance (Hazell et al. 2007), especially for elderly people (Suzuki et al. 2001). Thereby, impairments in muscle power in the lower limbs in elderly are more critical in limiting the performance of daily living activities.

Previous findings have shown that muscle power declines, which occurs with aging, are sooner and faster than observed for others variables, like muscle strength (Metter et al. 1997; Young and Skelton 1994). Per year, the decline in muscle power is 3–4 % greater than the rate of decrease in muscle strength (Metter et al. 1997; Young and Skelton 1994). Thus, muscle power is more vulnerable to aging process than others neuromuscular variables. Therefore, interventions to increase muscle power are critical for elderly people, in order to restore mobility and performance in daily living activities (Macaluso and De Vito 2004).

The traditional resistance training, which incorporates heavy weights moved at a slow/moderate velocity, has been widely used and observed to attenuate the age-related effects on strength, muscle power, and performance in daily living activities (Henwood and Taaffe 2006). Although this mode of training has been widely used, the moderate velocity of execution may not greatly improve muscle power and performance in daily living activities (Earles et al. 2001; Henwood et al. 2008). Thereby, power training, where the concentric movements are performed at high velocities, has been recommended for elderly people (Porter 2006). During power training, due to high-velocity movements, changes in motor unit behavior may occur, as earlier activation of motor units, extra doublets, and enhanced maximal firing rate (Fielding et al. 2002a), which may improve mobility and performance in daily living activities beyond the traditional resistance training.

Regarding increases in muscle power from lower limb muscles, some previous experimental studies reported superiority for power training compared to traditional resistance training (Fielding et al. 2002a; Ramirez-Campillo et al. 2014b; Straight et al. 2015), whereas others did not find differences between training modes (Henwood et al. 2008; Miszko et al. 2003a; Wallerstein et al. 2012) in older population. With regard to functional performance, a meta-analyses (Steib et al.

2010) reported that power training is more beneficial to improve the ability to raise from a chair and stair climbing, while no differences between training modes on timed up and go and walking tests were observed. Another meta-analysis (Tschopp et al. 2011) found a small to moderate effect on functional performance in favor of power training, since confidence intervals suggest no clinical relevant benefits from power training. Thus, the comparison between traditional resistance training and power training to improve muscle power and physical performance has led to inconclusive findings and more studies are needed to clarify the benefits both two training modes.

Beyond velocity of execution, it has been shown that the load utilized has an essential role in increasing strength and power output (Siegel et al. 2002). Usually, load has been controlled by percentage of one maximal repetition (%1-RM) (Hakkinen et al. 2001), and number of maximum repetitions (RMs) (Cadore et al. 2012). In both cases, subjects perform a maximum effort and this test may cause discomfort and/or muscle damage (Adams et al. 2000; Latham et al. 2004). In addition, exercise series until concentric failure (maximal repetitions—RMs), may represent an effort uncomfortable for most subjects, especially beginners and sedentary (Focht 2007; Glass and Stanton 2004; Perri et al. 2002).

Thereby, another approach to control training effort is using ratings of perceived exertion (RPE), based on the physical sensations that a person experiences during physical activity, including increased heart rate, increased respiration or breathing rate, increased sweating, and muscle fatigue (Robertson and Noble 1997). Previous studies reported that RPE have relations with the weight used to perform resistance exercises in slow and moderate velocities (Gearhart et al. 2002; Lagally et al. 2002a) and using fast velocity (Row et al. 2012). Thus, the use of RPE allows replacement of the traditional strength tests, avoiding maximum efforts (Tiggemann et al. 2010). In addition, its use enables the combined assessment of factors like discomfort, fatigue, and individual recovery state for each training session (Scott et al. 2016). Thus, RPE seems an efficient method to control training intensity. However, few studies have investigated the effects of traditional resistance and power training using RPE to control intensity in elderly people (Nelson et al. 1994; Row et al. 2012). Furthermore, in these studies, the purposes were associated with fracture risk associated with osteoporosis and

flexibility and not to the development of strength and muscle power. Thus, there is a lack of studies comparing effects of traditional resistance training and power training using RPE. More information on the effectiveness of RPE in increasing strength and muscle power can help professionals on the design of training programs, also increasing the adherence of novice subjects in early stages of training (Gearhart et al. 2002).

Therefore, the purpose of this study was to compare the effects of 12 weeks of traditional resistance training and power training, using RPE to determine training intensity, on improvements in strength, muscle power, and ability to perform functional task in older women. Despite knowing that increases in velocity during strength exercises generate a reduced perception of effort (Kleiner et al. 1999), the hypothesis of our study was that the magnitude of changes in movement velocity are not sufficient to cause significant differences in the strength, power, and functional variables.

Methods

Subjects

The number of participants required for the present investigation was calculated using G*Power software (version 3.0.1), with an alpha level of 0.05, a power of 90 %, and an effect size of 0.25 based on the maximal dynamic strength (i.e., leg extension) outcome from previous studies (Fielding et al. 2002b; Henwood and Taaffe 2006; Seynnes et al. 2004). A sample size of 12 subjects per group was estimated to test our hypothesis. However, 15 participants were included in each group due to the possible sample loss along the training.

Thirty healthy elderly women (60–75 years) who have not participated in a resistance training program for at least 6 months and have not been involved in planned exercise with a weekly frequency greater than or equal to twice a week, volunteered for the study. All subjects were free from cardiovascular diseases and metabolic or orthopedic conditions that would prohibit them from performing physical exercises. Subjects were carefully informed of the purpose, procedures, benefits, risks, and discomfort that might result from this study. Thereafter, subjects gave their written informed consent to participate. The institutional research ethics committee approved all procedures of the present study. Participants were randomly assigned to a traditional

resistance training group (TRT; $n = 15$; 65.6 ± 5.3 years; 65.2 ± 8.8 kg; 155 ± 5.0 cm; 26.8 ± 3.0 kg m⁻²) and a power training group (PT; $n = 15$; 64.4 ± 4.0 years; 66.0 ± 10.5 kg; 157.2 ± 5.6 cm; 26.7 ± 4.3 kg m⁻²). At pre-training, a one-way analysis of variance (ANOVA) between groups assured the similar initial values for all dependent variables. Figure 1 depicts the steps to recruit and allocate participants to the experimental groups.

Experimental design

The experimental period of 16 weeks consisted of a 4-week control period followed by a 12-week training period. Firstly, subjects underwent two familiarization sessions that included instructions regarding correct technique and performance of all tests used in the study. After familiarization, 4 weeks of the study period (between the measurement at weeks -4 and 0) were used as control period when no training was carried out. Subjects were tested before and after this period. Thereafter, subjects started a supervised experimental training period for 12 weeks either assigned at TRT group or PT group. Measurements were repeated at the end of the training period. All measurements were performed by the same investigator using identical procedures in a single-blinded fashion. Subjects were instructed to avoid any changes in their diet or recreational physical activities (e.g., walking, jogging, biking, and aerobics) during the course of study.

Training program

Participants trained for 12 weeks, completing two workouts per week, in nonconsecutive days (i.e., 24 training sessions). In each training session, both groups performed the following exercises in this order: bilateral leg press, bench press, bilateral knee extension, seated row machine, bilateral leg curl, and abdominal crunch. With exception of crunch abdominal exercise, all exercises were performed on machines with weight columns (Ajustfitness, Caxias do Sul, Brazil). During the first 2 weeks of training, both groups performed concentric and eccentric phase of each repetition with 2 s each. After this period, the PT group performed all exercises for lower-body muscles moving the weights as fast as possible in the concentric phase and taking 2 s to complete the eccentric phase, while the TRT group continuously performed concentric and eccentric

Fig. 1 Design of participant recruitment and location. *TRT* traditional resistance training, *PT* power training

phases for 2 s each. All training sessions were supervised by at least two trained technicians and were performed in the Faculty of Serra Gaúcha gymnastic room.

The intensity of exercises was determined using ratings perceived exertion (RPE) Borg scale (ratings 6 to 20) (Borg 1970). For assessing RPE during exercises, standard instructions and anchoring procedures were explained during two familiarization sessions (Gearhart et al. 2001). The training protocol utilized is presented in Table 1. The RPE ranged between 13 and 18 and their respective percentage of 1-RM was based in previous studies (Lagally et al. 2002b; Sweet et al. 2004; Tiggemann et al. 2010). During the training period, after the last set of each exercise, subjects were asked “how would you rate your effort?” The question was answered by giving a RPE value to describe the effort of exercise. According to the response, if RPE was between one rating value above or below the pre-defined value, the weight was not modified. However, if RPE was two rating values above or below from the pre-defined value, the weight was modified for the next workout between 5 and 10 %. The amount of rest between sets was standardized for all subjects in 2 min.

Maximal dynamic strength

Subjects performed the one-repetition maximum (1-RM) tests for leg press and knee extension on the same equipment used during training. Thereafter, they performed one set of 8–10 repetitions for each exercise with a light load as warm up. After 3 min of rest, the resistance was increased until they were unable to lift the additional weight throughout the full range of motion. Complete range of motion, proper technique, and appropriate cadence (2 s concentric and 2 s eccentric) were required for successful trials. All values of 1-RM were determined within five attempts with rests of 3–5 min between each trial and 10 min between different exercises.

Maximal vertical jump

Squat jump (SJ) and counter movement jump (CMJ) were performed on a AMTI OR6-6WP force platform capturing data at 1000 Hz, calibrated before the test according the manufacturer’s instructions and interfaced with a personal computer with the software AMTIforce.

Table 1 Training protocol for the traditional strength training and power training

Week	Traditional resistance training	Power training	RPE	Respective % 1-RM
1–2	2 × 15	2 × 15	13 ± 1	45
3–4	2 × 15	2 × 15	14 ± 1	
5–6	2 × 12	2 × 12	15 ± 1	55
7–8	2 × 12	2 × 12	16 ± 1	
9–10	3 × 8	3 × 8	17 ± 1	65
11–12	3 × 8	3 × 8	18 ± 1	

RPE ratings of perceived exertion

Before maximal tests, subjects were familiarized with the procedures by performing 3–4 trials.

For the SJ, subjects were instructed to stay on the platform with their feet in shoulder width distance and hands placed on the side of the hips. Subjects squatted until their thighs were approximately parallel to the floor and maintained this position for a count of 3 s, after which subjects explosively jumped vertically. The only movement permitted during the explosive phase of the jump was upward. For performance of the CMJ jump, they were also instructed to stay on the platform with their feet in shoulder width distance and hands placed on the side of the hips. Subjects squatted until their thighs were approximately parallel to the floor and downward movement was followed immediately by an explosive upward vertical jump. In both tests, they were instructed to jump as high as possible while avoiding horizontal displacement and without bending their knees during flight time. No more than six attempts were necessary to determine the highest SJ and CMJ for each participant. Subjects were permitted 2 min of rest between trials of the same type of jump and between sets of different types of jump. The height of the jumps was determined by the equation provided in a previous study (Bosco et al. 1983) ($\text{height} = 9.8 \cdot (\text{flight time})^2/6$) using the MATLAB software (Bosco et al. 1983). The highest SJ and CMJ height achieved were used in the statistical analysis.

Rate of force development

The rate of force development (RFD) over time interval of 0–100 ms (RFD100) and the maximal RFD (RFDmax) were calculated from the force-time curve ($\Delta\text{force}/\Delta\text{time}$) obtained during the highest SJ. The RFD100 was calculated as the average of the force

produced during the first 0–100 ms, while that RFDmax was calculated as the maximal force produced during SJ divided by the time taken to achieve peak force. The onset of muscle contraction was defined as the time point at which the curve exceeded subject's body mass.

Functional performance

All subjects undertook a series of tests to assess their functional capacity (Henwood and Taaffe 2006). For each test, subjects were instructed to move safely but as fast as possible. The time taken to perform test was assessed using a manual stopwatch (Casio S 70, Tokyo, Japan). In each day, the tests were performed in duplicate (except 6-min walking test, performed only once), with 5 min of rest between trials of the same type of test and 20 min between different tests. The average of trials, in the second day of test, was used for statistical analyses.

Six-minute walking test

The 6-min walking test was conducted in a 54-m course. A line was made at each end of the walkway to indicate where subjects had to turn. Subjects were instructed to “walk as far as possible during 6 minutes.” They were instructed to walk continuously, if possible, but they could slow down or stop if necessary. The outcome measure was the total distance covered in 6 min.

Stair climb

Subjects were required to climb 10 stairs (0.18 m high and 0.30 m long) as fast as possible, without using the handrails. The stopwatch was started when the participant's foot touched the first step and was stopped when both feet were at the top of the tenth step.

Timed up and go (TUG)

For the TUG test, subjects sat on a standard chair (0.43 m height from the floor) and were instructed to get up and walk for 3 m, to a cone on the floor, walk around the cone, return, and sit all the way back in the chair as fast as possible. Time was recorded to the nearest millisecond from the time the person's buttocks left the chair until his/her return to the chair.

Chair rise to standing (CRS)

The chair rise to standing (CRS) was performed with a standard chair (0.43 m height from the floor). Subjects remained seated on the chair with both hands crossed over their chest and feet shoulder width apart. The test started with a verbal signal, and then subjects rose to a standing positing and returned to a fully sited position five times as fast as possible.

Statistical analysis

All results are presented as means $\pm$ standard deviations. The normality and homogeneity for outcome measurements were tested using Shapiro-Wilk and Levene's tests, respectively. The variables RFD100 and 6-MWT were transformed to their base 10 logarithms to ensure normality. Statistical comparisons in the control period (from week -4 to week 0) within groups were performed using Student's paired *t* tests. The Mann-Whitney test was used to compare between groups for the scores regarding health stage and physical activity level at pre training. Unpaired *t* tests were used to test significant differences between groups before training period. Training-related effects were assessed using a two-way analysis of variance (ANOVA) with repeated measures (group vs. time). Bonferroni post hoc tests were used to test for pairwise differences when significant main effects were observed. All statistical tests were evaluated for statistical significance at $\alpha = 0.05$. All tests were conducted using SPSS version 17.0 (Chicago, IL).

Results

Subjects

No significant differences ($p > 0.05$) were observed between groups for the descriptive variables (weight, height, and BMI) at baseline.

Training intensity

In Table 2, training intensity relative to percentage of 1-RM and RPE utilized in all exercises during the training period for both groups is presented. There was no significant difference between groups for

percentage of 1-RM and RPE utilized throughout the training period ($p > 0.05$).

Maximal dynamic strength

At baseline, there was no significant difference between groups in any of the three exercises tested ($p > 0.05$). The two-way ANOVA showed a significant main effect for time for leg press and knee extension 1-RM in both groups ($p < 0.001$); however, there was no differences between groups ($p > 0.05$).

After training period, both groups had significant increases in 1-RM for leg press (56.3 ± 14.5 % for the TRT group and 60.3 ± 20.5 % for the PT group) and knee extension (16.1 ± 5.9 % for the TRT group and 22.9 ± 11.6 % for the PT group) (Fig. 2).

Maximal vertical jump

There were no significant differences between groups in SJ and CMJ, at baseline ($p > 0.05$). The two-way ANOVA showed a significant main effect for time SJ and CMJ ($p \leq 0.001$); however, there were no differences between groups ($p > 0.05$).

After training period, significant increases ($p < 0.001$) occurred in SJ height (25.6 ± 15.7 % for the TRT group and 34.3 ± 22.7 % for the PT group) and CMJ (21.5 ± 19.7 % for the TRT group and 28.3 ± 20.7 % for the PT group) (Table 3).

Table 2 Mean of the percentage one-repetition maximum and the rate the perceived exertion utilized in all exercises throughout the training period

Week	Traditional resistance training (<i>n</i> = 13)		Power training (<i>n</i> = 12)	
	%1-RM	RPE	%1-RM	RPE
1–2	45.1 $\pm$ 2.3	12.7 $\pm$ 0.8	45.1 $\pm$ 4.0	12.7 $\pm$ 0.9
3–4	50.2 $\pm$ 7.7	13.1 $\pm$ 0.7	50.6 $\pm$ 10.3	13.4 $\pm$ 1.1
5–6	60.3 $\pm$ 4.5	13.9 $\pm$ 0.7	60.1 $\pm$ 5.0	13.9 $\pm$ 0.8
7–8	69.1 $\pm$ 9.3	16.4 $\pm$ 0.8	68.4 $\pm$ 11.0	16.3 $\pm$ 0.7
9–10	69.3 $\pm$ 3.4	15.6 $\pm$ 1.1	67.4 $\pm$ 3.1	15.8 $\pm$ 1.1
11–12	75.5 $\pm$ 7.7	17.5 $\pm$ 0.6	73.9 $\pm$ 7.0	17.3 $\pm$ 0.8

%1-RM percentage of one-repetition maximum, RPE ratings of perceived exertion

Fig. 2 Absolute values (mean $\pm$ SD; kg) of one-repetition maximum (1-RM) of leg press (a) and knee extension (b) before and following 12 weeks of training. TRT traditional resistance training ($n = 13$), PT

power training ($n = 12$). Asterisks represent significant differences between pre- and post-training ($p < 0.001$)

Rate of force development and time to peak of force

There were no significant differences between groups for RFD100, RFDmax, or time to maximum strength at baseline ($p > 0.05$). The two-way ANOVA showed a significant main effect for time RFD100 and time to peak of force in both groups ($p < 0.001$); however, there were no differences between groups ($p > 0.05$).

After training program, both groups significantly ($p < 0.05$) and similarly increased the RFD100 and reduced the time to peak of force during the SJ test (Table 3).

Functional performance

At baseline, there were no significant differences in any test used to assess the functional performance ($p > 0.05$). For the 6-min walking test, stair climb, TUG, CRS, and

6-m walk the ANOVA showed a significant main effect for time for both groups ($p < 0.001$). Furthermore, there were significant differences between groups at the 6-m walk test ($p < 0.05$). Significant increases in physical performance occurred after training in both groups for 6-min walking test (6.8 ± 6.1 % for the TRT group and 8.7 ± 5.4 % for the PT group), stair climb (15.1 ± 7.6 % for the TRT group and 18.6 ± 14.7 % for the PT group), TUG (11.2 ± 7.2 % for the TRT group and 5.2 ± 11.8 % for the PT group), and CRS (20.0 ± 10.0 % for the TRT group and 12.1 ± 10.0 % for the PT group) (Table 4).

Discussion

The purpose of this study was to compare the effects of 12 weeks of PT and TRT using RPE to determine

Table 3 Absolute values (mean $\pm$ SD) before and following 12 weeks of training in the squat jump and counter movement jump variables

Variable	Traditional resistance training ($n = 13$)		Power training ($n = 12$)	
	Pre	Post	Pre	Post
Squat jump (cm)	6.8 ± 2.0	$8.4 \pm 2.2^*$	7.1 ± 2.0	$9.2 \pm 2.0^*$
Counter movement jump (cm)	8.5 ± 2.2	$10.1 \pm 2.3^*$	8.7 ± 2.6	$10.7 \pm 2.7^*$
RFD100 (N/ms)	1042.2 ± 1115.8	$1819.1 \pm 824.9^*$	1610.4 ± 1041.4	$2456.6 \pm 1204.7^*$
RFDmax (N/ms)	1150.2 ± 702.8	1266.2 ± 451.5	1460.8 ± 596.4	1575.1 ± 691.1
Time to peak of force (s)	0.41 ± 0.1	$0.32 \pm 0.1^*$	0.33 ± 0.1	$0.28 \pm 0.1^*$

RFD rate of force development

*Significant increase from pre training values ($p < 0.001$)

Table 4 Functional performance before and following 12 weeks of training

Variable	Traditional resistance training (<i>n</i> = 13)		Power training (<i>n</i> = 12)	
	Pre	Post	Pre	Post
6-min walking test (m)	568.0 ± 35.5	606.6 ± 38.3*	566.1 ± 45.5	614.2 ± 44.5*
Stair climb (s)	4.3 ± 0.3	3.7 ± 0.5*	4.3 ± 0.3	3.5 ± 0.3*
TUG (s)	6.9 ± 0.7	6.2 ± 0.6*	6.7 ± 0.4	6.3 ± 0.4*
CRS (s)	14.2 ± 1.7	11.3 ± 1.3*	13.2 ± 1.5	11.4 ± 0.9*

TUG timed up and go, *CRS* chair rising and standing

*Significant increase from pre-training values ($p < 0.001$)

training intensity on strength, muscle power, and ability to perform functional task in older women. The main findings of the present study were that both programs significantly and similarly enhanced strength, muscle power, and functional performance. These findings support the effectiveness of TRT and PT, using RPE to control training load to mitigate harmful aging effects in elderly women.

Both groups showed significant improvements after 12 weeks of training in strength and power, and increases found in the current study were similar to those reported in previous studies which utilized %1-RM or RMs for controlling training intensity (Correa et al. 2012; Miszko et al. 2003a; Ramirez-Campillo et al. 2014a). The literature has shown strong correlations between load and RPE level during strength training sessions (Tiggemann et al. 2010). Likewise, it is known that higher velocity of execution generates a lower RPE when compared to lower velocities (Kleiner et al. 1999). Thus, while the PT group used higher velocities, this change did not lead to differences in loads (Table 2). Moreover, the literature has shown that small differences in loads may not represent consistent or functional changes in neuromuscular responses (Rabelo et al. 2004). Rabelo et al. (2004), with only 10 weeks of traditional strength training intervention, found similar responses in total force between two different intensities (50 vs 80 % 1-RM), being justified by methodological differences between studies and the participants' fitness level. Regarding power training, we found only one study that compared different loads on PT (20 vs 50 vs 80 % 1-RM) and showed that while maximum strength gains were higher in the group that trained with the highest loads (13 vs 16 vs 20 %, $p < 0.05$, respectively), similar power gains were found (≈ 15 %, $p < 0.05$) (De Vos et al. 2005). So it seems that muscle power

could be trained using varied loads (20–80 % of 1-RM), which is not the case for muscle strength.

Furthermore, our study adds that traditional resistance training using REP may also be used to increase muscle power from the lower limbs in elderly women. Regarding power training, to our knowledge, this is the first study that showed increases in power following a training period using RPE to control load. It has been reported that improvements in muscle power are achieved by performing exercises with maximal movement velocity and using different intensities (Siegel et al. 2002). In the present study, subjects from the PT group performed each repetition with maximal velocity, so it is possible to ascertain that RPE used during training corresponded to 40–70 % of 1-RM.

There were no significant differences between groups regarding improvements in maximal strength from the lower limb muscles. These findings are similar to those previously reported for elderly subjects, which also did not show significant differences between traditional strength training and power training in increases of maximal strength of lower limbs (Henwood et al. 2008; Ramirez-Campillo et al. 2014b; Wallerstein et al. 2012). Together, these results may suggest that traditional strength training and power training are equally effective in increasing the capacity to produce maximal strength. It has been shown that training load have an impact on strength gains (Mitchell et al. 2012), due to combined morphological and neural adaptations. Previous studies reported similar muscle hypertrophy and neural adaptations for traditional resistance training and power training (Nogueira et al. 2009; Wallerstein et al. 2012). Thus, it is possible to suggest that, in the current study, both groups had a similar muscle hypertrophy and neural drive increments that have been

transferred to maximal strength. In this way, the option for power training to increase maximal strength in elderly people may be a good alternative, because power training compared to traditional resistance training can be used to reduce workload per exercise session (Henwood et al. 2008) which may increase the adherence of participants.

It has been reported that traditional strength training may promote small enhancements in performance of SJ and CMJ (Ramirez-Campillo et al. 2014a). However, power training has been showed to be very effective in improving the performance of old subjects in CMJ (Ramirez-Campillo et al. 2014a). So, it was expected a larger enhance in SJ and CMJ performance in the PT group. However, in the present study, both groups improved significantly and similarly the ability to perform SJ and CMJ. These findings are in accordance with two previous studies that did not show differences between traditional resistance training and power training in improvements of CMJ ability in elderly women (Correa et al. 2012; Ramirez-Campillo et al. 2014a). Increases in the ability to perform jumps have been associated with strength gains in upper and lower leg muscles (Sanborn et al. 2000). In our study, subjects obtained similar gains in maximal strength, which may be explained by similar improvements in SJ and CMJ. However, more studies comparing power training and traditional strength training and improvements in ability to perform SJ and CMJ are necessary.

After training, both groups showed similar increases in the RFD100 and reductions in time to maximum strength. Our results suggest that elderly women could perform a traditional resistance training and power training to obtain significant improvement in explosive force production of lower limbs. The training using high velocity is well recognized to enhance RFD in elderly subjects; likewise, our results show that traditional resistance training may also be a useful tool to improve the RFD in elderly women. The generation of explosive force can be explained from a combination of morphological and neural factors (Folland et al. 2014). Recently, it has been shown that, at the initial 100 ms of contraction, the neuromuscular activation and maximal voluntary force seem to be largely determinants of RFD (Folland et al. 2014). Previous studies have shown that traditional resistance training and power training equally are effective to promote muscle strength gains and neural adaptations (Nogueira et al. 2009; Wallerstein et al. 2012). Thus, in the current study, both

training modes promoted similar improvements, which may suggest that traditional resistance training and power training contributed similarly to factors associated with RFD100 and time to maximum strength. These improvements, mainly in RFD100, represent significant benefits for elderly performing daily living tasks, because it has been shown that improvements in RFD are associated with better posture control and balance (Izquierdo et al. 1999), increasing neuromuscular economy (Cadore et al. 2011) and diminishing the risk of falls (Pijnappels et al. 2008).

In the current study, both training programs showed significant and similar effectiveness in improving functional performance. These results are in accordance with a previous study which did not find significant differences between traditional resistance training and power training (Henwood et al. 2008); in contrast, it is contrary with many others that found superior gains with power training in functional performance (Miszko et al. 2003a; Ramirez-Campillo et al. 2014a). Although there are many studies reporting the superiority of power training, our findings support previous suggestions that functional improvements are not exclusively limited to training performed in high velocity, so traditional resistance training can also provide benefits (Miszko et al. 2003a). This improvement in functional performance has key importance for elderly population. It has been shown that better performance during walking and raising from a chair is associated with better daily life activities and locomotion, improved health, and improvement in quality of life (Mosallanezhad et al. 2014; Ramirez-Campillo et al. 2014b). Thus, our results reinforce the suggestion that power training and traditional resistance training are useful tools to mitigate the effects of aging on functional performance.

In general, the present study confirms that the use of perceived exertion in traditional or high-velocity training leads to increases in neuromuscular and functional responses. However, no difference was found between groups, which may be justified by several factors. Possibly, the velocity of the concentric phase was not sufficiently different (for example, while the TRT performing the concentric phase in 2 s, the PT did so at maximum velocity which could suggest approximately 1 s per repetition) (Fielding et al. 2002b; Miszko et al. 2003b). Furthermore, during training, elapse and the consequential load increase possibly caused a speed reduction. Finally, the sample consisted of women between 60 and 75 years in good health, different to

previous studies which highlighted that TP has been more effective in functionally debilitated populations or older ages (Rice and Keogh 2009). The lack of velocity measurements may have limited our control of the velocity for the PT group, which can be further amended by the use of accelerometers or isokinetic equipment. In addition, the lack of a control group, may also have limited the results of this study. For future studies, we suggest conducting a training for a longer period and in other populations to assess if the observed results would be sustained.

Conclusion

In summary, traditional resistance training and power training using RPE scale to control intensity were significantly and similarly effective in improving maximal strength, muscle power, and functional performance of lower limbs in elderly women. In additional, these outcomes have an important practical application for the design of resistance training programs, because they show that RPE may be used with elderly women for effective enhancements in muscle and physical function.

Compliance with ethical standards Subjects gave their written informed consent to participate. The institutional research ethics committee approved all procedures of the present study

References

- Aagaard P, Suetta C, Caserotti P, Magnusson SP, Kjaer M (2010) Role of the nervous system in sarcopenia and muscle atrophy with aging: strength training as a countermeasure. *Scand J Med Sci Sports* 20:49–64. doi:[10.1111/j.1600-0838.2009.01084.x](https://doi.org/10.1111/j.1600-0838.2009.01084.x)
- Adams KJ, Swank AM, Barnard KL, Berning JM, Sevene-Adams PG (2000) Safety of maximal power, strength, and endurance testing in older African American women. *J Strength Cond Res* 14:254–260
- Berger MJ, Doherty TJ (2010) Sarcopenia: prevalence, mechanisms, and functional consequences. *Interdiscip Top Gerontol* 37:94–114. doi:[10.1159/000319997](https://doi.org/10.1159/000319997)
- Borg G (1970) Perceived exertion as an indicator of somatic stress. *Scand J Rehabil Med* 2:92–98
- Bosco C, Komi PV, Tihanyi J, Fekete G, Apor P (1983) Mechanical power test and fiber composition of human leg extensor muscles. *Eur J Appl Physiol Occup Physiol* 51:129–135
- Cadore EL et al. (2011) Neuromuscular economy, strength, and endurance in healthy elderly men. *J Strength Cond Res* 25: 997–1003. doi:[10.1519/JSC.0b013e3181d650ba](https://doi.org/10.1519/JSC.0b013e3181d650ba)
- Cadore EL et al. (2012) Strength prior to endurance intra-session exercise sequence optimizes neuromuscular and cardiovascular gains in elderly men. *Exp Gerontol* 47:164–169. doi:[10.1016/j.exger.2011.11.013](https://doi.org/10.1016/j.exger.2011.11.013)
- Correa CS et al. (2012) 3 different types of strength training in older women. *Int J Sports Med* 33:962–969. doi:[10.1055/s-0032-1312648](https://doi.org/10.1055/s-0032-1312648)
- De Vos NJ, Singh NA, Ross DA, Stavrinou TM, Orr R, Singh MAF (2005) Optimal load for increasing muscle power during explosive resistance training in older adults. *J Gerontol A Biol Sci Med Sci* 60:638–647
- Earles DR, Judge JO, Gunnarsson OT (2001) Velocity training induces power-specific adaptations in highly functioning older adults. *Arch Phys Med Rehabil* 82:872–878. doi:[10.1053/apmr.2001.23838](https://doi.org/10.1053/apmr.2001.23838)
- Fielding RA, LeBrasseur NK, Cuoco A, Bean J, Mizer K, Fiatarone Singh MA (2002a) High-velocity resistance training increases skeletal muscle peak power in older women. *J Am Geriatr Soc* 50:655–662
- Fielding RA, LeBrasseur NK, Cuoco A, Bean J, Mizer K, Fiatarone Singh MA (2002b) High-velocity resistance training increases skeletal muscle peak power in older women. *J Am Geriatr Soc* 50:655–662. doi:[10.1046/j.1532-5415.2002.50159.x](https://doi.org/10.1046/j.1532-5415.2002.50159.x)
- Focht BC (2007) Perceived exertion and training load during self-selected and imposed-intensity resistance exercise in untrained women. *J Strength Cond Res* 21:183–187
- Folland JP, Buckthorpe MW, Hannah R (2014) Human capacity for explosive force production: neural and contractile determinants. *Scand J Med Sci Sports* 24:894–906. doi:[10.1111/sms.12131](https://doi.org/10.1111/sms.12131)
- Gearhart RF, Goss FL, Lagally KM, Jakicic JM, Gallagher J, Robertson RJ (2001) Standardized scaling procedures for rating perceived exertion during resistance exercise. *J Strength Cond Res* 15:320–325
- Gearhart RF Jr, Goss FL, Lagally KM, Jakicic JM, Gallagher J, Gallagher KI, Robertson RJ (2002) Ratings of perceived exertion in active muscle during high-intensity and low-intensity resistance exercise. *J Strength Cond Res/Natl Strength Cond Assoc* 16:87–91
- Glass SC, Stanton DR (2004) Self-selected resistance training intensity in novice weightlifters. *J Strength Cond Res* 18: 324–327
- Hakkinen K, Pakarinen A, Kraemer WJ, Hakkinen A, Valkeinen H, Alen M (2001) Selective muscle hypertrophy, changes in EMG and force, and serum hormones during strength training in older women. *J Appl Physiol* 91:569–580
- Hazell T, Kenno K, Jakobi J (2007) Functional benefit of power training for older adults. *J Aging Phys Act* 15:349–359
- Henwood TR, Taaffe DR (2006) Short-term resistance training and the older adult: the effect of varied programmes for the enhancement of muscle strength and functional performance. *Clin Physiol Funct Imaging* 26:305–313. doi:[10.1111/j.1475-097X.2006.00695.x](https://doi.org/10.1111/j.1475-097X.2006.00695.x)
- Henwood TR, Riek S, Taaffe DR (2008) Strength versus muscle power-specific resistance training in community-dwelling older adults. *J Gerontol Series A, Biol Sci Med Sci* 63:83–91
- Izquierdo M, Aguado X, Gonzalez R, Lopez JL, Hakkinen K (1999) Maximal and explosive force production capacity and balance performance in men of different ages. *Eur J*

- Appl Physiol Occup Physiol 79:260–267. doi:[10.1007/s004210050504](https://doi.org/10.1007/s004210050504)
- Kleiner DM, Blessing DL, Mitchell JW, Davis WR (1999) A description of the acute cardiovascular responses to isokinetic resistance at three different speeds. *J Strength Cond Res* 13: 360–366
- Lagally KM, Robertson RJ, Gallagher KI, Gearhart R, Goss FL (2002a) Ratings of perceived exertion during low- and high-intensity resistance exercise by young adults. *Percept Mot Skills* 94:723–731. doi:[10.2466/pms.2002.94.3.723](https://doi.org/10.2466/pms.2002.94.3.723)
- Lagally KM, Robertson RJ, Gallagher KI, Gearhart R, FL G (2002b) Ratings of perceived exertion during low- and high-intensity resistance exercise by young adults. *Percept Mot Skills* 94:723–731
- Latham NK, Bennett DA, Stretton CM, Anderson CS (2004) Systematic review of progressive resistance strength training in older adults. *J Gerontol A Biol Sci Med Sci* 59:48–61
- Macaluso A, De Vito G (2004) Muscle strength, power and adaptations to resistance training in older people. *Eur J Appl Physiol* 91:450–472. doi:[10.1007/s00421-003-0991-3](https://doi.org/10.1007/s00421-003-0991-3)
- Metter EJ, Conwit R, Tobin J, Fozard JL (1997) Age-associated loss of power and strength in the upper extremities in women and men. *J Gerontol Series A, Biol Sci Med Sci* 52:B267–B276
- Miszko TA, Cress ME, Slade JM, Covey CJ, Agrawal SK, Doerr CE (2003a) Effect of strength and power training on physical function in community-dwelling older adults. *J Gerontol Series A, Biol Sci Med Sci* 58:171–175
- Miszko TA, Cress ME, Slade JM, Covey CJ, Agrawal SK, Doerr CE (2003b) Effect of strength and power training on physical function in community-dwelling older adults. *J Geront-Serie Biol Sci Med Sci* 58:171–175
- Mitchell CJ, Churchward-Venne TA, West DW, Burd NA, Breen L, Baker SK, Phillips SM (2012) Resistance exercise load does not determine training-mediated hypertrophic gains in young men. *J Appl Physiol* 113:71–77. doi:[10.1152/japplphysiol.00307.2012](https://doi.org/10.1152/japplphysiol.00307.2012)
- Mosallanezhad Z, Salavati M, Sotoudeh GR, Nilsson Wikmar L, Frandin K (2014) Walking habits and health-related factors in 75-year-old Iranian women and men. *Arch Gerontol Geriatr* 58:320–326. doi:[10.1016/j.archger.2013.11.008](https://doi.org/10.1016/j.archger.2013.11.008)
- Nelson ME, Fiatarone MA, Morganti CM, Trice I, Greenberg RA, Evans WJ (1994) Effects of high-intensity strength training on multiple risk factors for osteoporotic fractures. A randomized controlled trial. *JAMA* 272:1909–1914
- Nogueira W, Gentil P, Mello SN, Oliveira RJ, Bezerra AJ, Bottaro M (2009) Effects of power training on muscle thickness of older men. *Int J Sports Med* 30:200–204. doi:[10.1055/s-00028-1104584](https://doi.org/10.1055/s-00028-1104584)
- Perri MG, Anton SD, Durning PE, Ketterson TU, Sydeman SJ, Berlant NE, Kanasky WF Jr, Newton RL Jr, Limacher MC, Martin AD (2002) Adherence to exercise prescriptions: Effects of prescribing moderate versus higher levels of intensity and frequency. *Health Psychol* 21:452–458
- Pijnappels M, van der Burg PJ, Reeves ND, van Dieën JH (2008) Identification of elderly fallers by muscle strength measures. *Eur J Appl Physiol* 102:585–592. doi:[10.1007/s00421-007-0613-6](https://doi.org/10.1007/s00421-007-0613-6)
- Porter MM (2006) Power training for older adults applied physiology, nutrition, and metabolism. *Physiol Appl, Nutr Et Metab* 31:87–94. doi:[10.1139/h05-034](https://doi.org/10.1139/h05-034)
- Rabelo HT, Oliveira RJ, Bottaro M (2004) Effects of resistance training on activities of daily living in older women. *Biol Sport* 21:325–336
- Ramirez-Campillo R et al. (2014a) High-speed resistance training is more effective than low-speed resistance training to increase functional capacity and muscle performance in older women. *Exp Gerontol* 58C:51–57. doi:[10.1016/j.exger.2014.07.001](https://doi.org/10.1016/j.exger.2014.07.001)
- Ramirez-Campillo R et al. (2014b) High-speed resistance training is more effective than low-speed resistance training to increase functional capacity and muscle performance in older women. *Exp Gerontol* 58:51–57. doi:[10.1016/j.exger.2014.07.001](https://doi.org/10.1016/j.exger.2014.07.001)
- Rice J, Keogh JWL (2009) Power training: can it improve functional performance in older adults? A systematic review. *Int J Exerc Sci* 2:131–151
- Robertson RJ, Noble BJ (1997) Perception of physical exertion: methods, mediators, and applications. *Exerc Sport Sci Rev* 25:407–452
- Row BS, Knutzen KM, Skogsberg NJ (2012) Regulating explosive resistance training intensity using the rating of perceived exertion. *J Strength Cond Res/Natl Strength Cond Assoc* 26: 664–671. doi:[10.1519/JSC.0b013e31822ac367](https://doi.org/10.1519/JSC.0b013e31822ac367)
- Sanborn K et al. (2000) Short-term performance effects of weight training with multiple sets not to failure vs. a single set to failure in women. *J Strength Cond Res* 14:328–331
- Scott BR, Duthie GM, Thornton HR, Dascombe BJ (2016) Training monitoring for resistance exercise: theory and applications. *Sports Med*. doi:[10.1007/s40279-015-0454-0](https://doi.org/10.1007/s40279-015-0454-0)
- Seynnes O, Singh MAF, Hue O, Pras P, Legros P, Bernard PL (2004) Physiological and functional responses to low-moderate versus high-intensity progressive resistance training in frail elders. *J Gerontol A Biol Sci Med Sci* 59:503–509
- Siegel JA, Gilders RM, Staron RS, Hagerman FC (2002) Human muscle power output during upper- and lower-body exercises. *J Strength Cond Res/Natl Strength Cond Assoc* 16: 173–178
- Steib S, Schoene D, Pfeifer K (2010) Dose-response relationship of resistance training in older adults: a meta-analysis. *Med Sci Sports Exerc* 42:902–914. doi:[10.1249/MSS.0b013e3181c34465](https://doi.org/10.1249/MSS.0b013e3181c34465)
- Straight CR, Lindheimer JB, Brady AO, Dishman RK, Evans EM (2015) 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*. doi:[10.1007/s40279-015-0418-4](https://doi.org/10.1007/s40279-015-0418-4)
- Suzuki T, Bean JF, Fielding RA (2001) Muscle power of the ankle flexors predicts functional performance in community-dwelling older women. *J Am Geriatr Soc* 49:1161–1167
- Sweet TW, Foster C, McGuigan MR, Brice G (2004) Quantitation of resistance training using the session rating of perceived exertion method. *J Strength Cond Res* 18:796–802
- Thompson BJ, Conchola EC, Palmer TB, Stock MS (2014) Effects of aging on maximal and rapid velocity capacities of the leg extensors. *Exp Gerontol* 58C:128–131. doi:[10.1016/j.exger.2014.07.019](https://doi.org/10.1016/j.exger.2014.07.019)
- Tiggemann CL, Korzenowski AL, Brentano MA, Tartaruga MP, Alberton CL, Kruel LF (2010) Perceived exertion in different strength exercise loads in sedentary, active, and trained adults. *J Strength Cond Res* 24:2032–2041. doi:[10.1519/JSC.0b013e3181d32e29](https://doi.org/10.1519/JSC.0b013e3181d32e29)

- Tschopp M, Sattelmayer MK, Hilfiker R (2011) Is power training or conventional resistance training better for function in elderly persons? A meta-analysis. *Age Ageing* 40:549–556. doi:[10.1093/ageing/afr005](https://doi.org/10.1093/ageing/afr005)
- Verbrugge LM, Jette AM (1994) The disablement process. *Soc Sci Med* 38:1–14
- Wallerstein LF et al. (2012) Effects of strength and power training on neuromuscular variables in older adults. *J Aging Phys Act* 20:171–185
- Young A, Skelton DA (1994) Applied physiology of strength and power in old age. *Int J Sports Med* 15:149–151. doi:[10.1055/s-2007-1021037](https://doi.org/10.1055/s-2007-1021037)