Effects of high-speed power training on functional capacity and muscle performance in older women

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A B S T R A C T

The purpose of the study was to examine the effects of 12 weeks high-speed power training on isometric contraction (handgrip strength), maximal strength (1RM), muscle power (walking velocity, counter movement jump and ball throwing) and functional tasks of the arm and leg muscles (sit-to-stand and get-up and go). Fifty-six older women were divided into an experimental group and a control group [EG, n=28, 62.5 (5.4) years; CG: n=28, 62.5 (4.3) years]. The EG was submitted to a high-speed power training that consisted of 40% of one repetition maximum (1-RM) to 75% of 1RM; 3 sets 4–12 reps, countermovement jump and medicine ball (1.5 kg) throwing. Over the 12-week training period, the EG significantly increased dynamic and isometric strength performance (57% to 61%), muscle power (range from 14% to 40%) (P<0.05) and function (P<0.05). No significant magnitudes of increase were observed in the CG. These data indicate that high-speed power training is an effective exercise approach leading to large gains in upper and lower extremity muscle performance and function capacity.

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1. Introduction

In older populations, maintenance of muscle power output is a key factor in everyday task performance, such as climbing stairs, rising from a chair and walking, as well as in decreasing the likelihood of falls, especially in women (Häkkinen et al., 1998; Izquierdo et al., 2001; Bonnefoy et al., 2007; Arnold et al., 2010). Resistance training (RT) in older people encourages slow-velocity contractions at a relatively high percentage of maximal strength (50–80%) to improve muscle strength and power (Porter, 2006). Recently, muscle power training has emerged as an important method in stimulating overall functioning capacity in the elderly (Häkkinen et al., 1998; Izquierdo et al., 2001). Indeed, a markedly lower capacity for concentric contractions may result in impaired performance, particularly in activities where intense and rapid movements are essential as, for example, avoiding oncoming traffic, counteracting a forward fall, climbing steps or crossing the road (Caserotti et al., 2008). The effectiveness of traditional resistance training programs on older populations has recently been questioned since these protocols in untrained older adults do not include fast and explosive activities (Häkkinen et al., 1998; Izquierdo et al., 2001). In fact, few studies have examined the effects of high-speed power training on maximal strength, muscle power and function in older women (Häkkinen et al., 1998; Izquierdo et al., 2001; Caserotti et al., 2008; Webber and Porter, 2010). Understanding the use of explosive training programs in older women is an important task for this relatively un-studied age group. The purpose of this study was therefore to examine the effect of a 12-week high-speed power training program for muscle strength and power development in older women. We hypothesized that a higher velocity RT in this population could be highly effective in promoting significant changes in strength and power values as well as in functional tasks.

2. Methods

2.1. Subjects

Fifty-six older Caucasian women were divided into two groups (hereafter EG and CG): the experimental (age: 62.5 ± 5.4 years; body mass: 68.2 ± 11.2 kg; height: 1.55 ± 0.06 cm) and the control (age: 62.2 ± 4.3 years, body mass: 66.2 ± 10.9 kg and height: 1.57 ± 0.06 cm) each one with 28 participants. Efforts were made to recruit subjects so
as to form comparable groups. Apart from routine daily tasks, the experimental group (EG) underwent a resistance training program of three training sessions per week over 12 weeks. The control group did not undergo any specifically orientated physical activity. None of the participants had a history of resistance training. Before inclusion in the study, all candidates were thoroughly screened by a physician. A written informed consent was obtained from each participant. The experimental procedures were approved by the University of Trás-os-Montes and Alto Douro, Department of Sport Sciences, following the Helsinki declaration.

2.2. Testing procedures

The evaluation process requires reliability, specificity and facility of application, especially when subjects are sedentary and inexperienced. We thus selected protocols that were time-economical and that had been previously used in several studies for the assessment of musculoskeletal function in older people (Häkkinen et al., 1997; Häkkinen et al., 2000; Tolea et al., 2010). All testing procedures were applied to both groups before the experimental period (T1) and after 12 weeks of training (T2). Testing (T1 and T2) took place over a period of three days (three sessions separated by 3 to 5 days), always in the same location and time and supervised by the same researchers. In the first session, all subjects were assessed on anthropometric factors: weight, height, blood-pressure, resting heart rate; some functional parameters (the get-up-and-go test and the sit-to-stand test) and maximum isometric handgrip strength. The second session (3 days later) involved measures of power (maximum walking velocity, vertical jump and medicinal ball throwing) and maximum dynamic strength (one-repetition maximum bench press and leg extension). Before testing, each subject was familiarized with all strength testing procedures, preceded by a general warm-up routine. Verbal encouragement was given throughout the voluntary test and biofeedback provided in order to maximize motivation.

2.3. Anthropometric measures

Total height (m) and body weight (kg) were assessed according to international standards for anthropometric assessment (Marfell-Jones et al., 2006). To evaluate height (cm) a stadiometer (SECA, model 225, Germany) with a scale range of 0.10 cm was used and body mass (kg) was measured to the nearest 0.1 kg using a digital scale (Philips, type HF 351/00). These parameters were assessed prior to any physical performance test. Subjects were tested whilst wearing shorts and t-shirts (shoes and socks were removed).

2.4. Strength tests

**One repetition maximum leg-extension:** Lower-body maximal strength was assessed using one repetition maximum leg-extension (1RMLE) (Izquierdo et al., 2005). The shoulders were in contact with the machine, and the starting point knee angle was 90° measured with a goniometric. On command, the subject performed a concentric leg extension (as fast as possible) starting from the sitting position when the time elapsed, the last acceptable extension with the highest possible load was determined as 1RMLE.

**One repetition maximum bench press:** Each subject was tested for maximal bilateral concentric one-repetition bench press (1RMbp). In the 1RMbp concentric performance, the bar was positioned 1 cm above the subject’s chest, supported by the bottom stops of the measurement device. The subject was instructed to perform from the starting position a purely concentric action maintaining the shoulders in a 90° abducted position (Newton et al., 1997). Specific warm-up was allowed. Thereafter, three to four trials were performed until the subject was unable to reach the fully extended position of the arms. The last acceptable extension with the highest possible load was determined as 1RMbp.

**Maximum isometric handgrip:** Maximum isometric strength of the forearm muscles (handgrip test) was measured in both hands (dominant — HGd; non-dominant — HGnd), using an adjustable mechanical hand dynamometer (Lafayette Instrument, Lafayette, IN). After a standard warm-up period, the subject was placed seated on a chair in an erect position with the 90° hip, knee and elbow flexion position. The subjects were then instructed to exert maximal grip over three trials, with brief pauses (3 min) between each attempt, the best result being chosen for analysis (Haidar et al., 2004).

2.5. Power tests

**Vertical jump:** A trigonometric carpet (Ergojump Digitime 1000; Digitest, Jyväskyla, Finland) was used to assess maximum height in counter-movement jump (CMJ) (Marques et al., 2008). Each subject started from an erect standing position and the end of the concentric phase corresponded to a full leg extension (180°). The test was performed three times, each separated by a 2-minute rest period. The average maximum height of three trials was adopted and expressed in centimeters (cm).

**Medicine ball throwing:** Ball throwing performance (BT) was tested with a 1.5 kg medicine ball (Ø 0.60 m). Prior to commencement, the participants were familiarized in throwing with different weighted balls in order to avoid a learning effect. Each subject sat on a chair with the posterior trunk region positioned against the chair back and held the ball to the front with both hands. They were instructed to throw the medicine ball as far and fast as possible. Torso and hip rotation was not allowed. Three approved attempts were made with one-minute rest intervals between each attempt to ensure that fatigue or learning effects did not influence the performance. The maximal throwing distance was determined using a flexible steel tape. Only the best attempt was used for further analysis (Marques et al., 2008).

**Walking velocity:** Subjects were instructed to perform three maximum effort sprints of 10 m (S10) (Holviala et al., 2006) beginning 2 m before the start line, in order to achieve optimal velocities over the test distance. Time at 0–10 m (S10) was recorded using Micrograte equipment (Racetime2 Light Radio Kit, USA). Subjects performed trial sprints, separated by 3 min of rest, in an indoor rubberized track.

2.6. Functional tasks

**Walking 2.44 m, turning, and returning to seated position “get-up and go”:** This test (GUG) enables dynamic balance assessment, represented by the total time required for the subjects to rise from a seated position, walk eight feet (2.44 m), turn and return to a seated position. Subjects were instructed to sit on the chair with back straight, feet flat on the floor, and hands on thighs (Rikli and Jones, 1999). The timer was started on the signal “go” whether or not the participant actually started to move and terminated when the subject sat back down on the chair. The procedure was visually demonstrated in advance, and each participant was allowed to practice it once. Following the practice, two test trials were administered.

**Sit-to-stand test:** Before starting the 30-second sit-to-stand test (STS) a straight-backed chair was placed next to a wall; subjects were asked to flex their arms across the chest and to stand up from a seated position on the chair. From the sitting position, the subject stood up to full height, then completely back down, this cycle being repeated as quickly as possible for 30 s. The total number of repetitions was recorded. Where the subject was in process of completing a full stand from the sitting position when the time elapsed, the final stand was counted in the total (Hallage et al., 2010).
2.7. High-speed power training protocol

The RT program consisted of three sessions per week over 12 consecutive weeks. Table 1 provides a detailed description of the training program. The RT program was supervised by two resistance training specialists to ensure that the participants correctly followed the training schedule. The control group was permitted the same recreational and social activities as the experimental group. After a 10 minute warm-up, which included brisk walking and several joint mobilization exercises, the leg extension and bench press training was initiated. Subjects performed 3 sets of 10 reps with a load of 40% of 1RM at the outset of their predetermined 1-repetition maximum up until 3 sets of 4 reps with load of 75% towards the end of the 12-week period. In each session, they performed curl-ups (3 sets of 12 reps) and lumbar exercises (3 sets of 10 reps). Two power exercises were then performed: the counter movement jump and medicine ball throw (1.5 kg). Rest intervals of 2 min between sets and 3 min between exercises were deployed. Although utilizing the bench press and leg extension, the program gradually progressed so that the subjects were performing all exercises at high velocity, with instructions to do them “as fast as you can”. Before completing the session, the participants performed a few exercises to improve stability, balance and stretching. The RT was conducted every Monday, Wednesday and Friday (10:00 p.m.), throughout the 12 weeks of training (during Spring 2011). The subjects did not undertake any additional formal strength training activities during the testing or training period. Each RT session lasted for approximately 60 min including the warm-up period.

2.8. Statistical analysis

Standard statistical methods were used for the calculation of means and standard deviations. The normality and homoscedasticity assumptions were checked respectively with the Shapiro–Wilks and the Levene Tests. The training-related effects were assessed using a two-way ANOVA with repeated measures (groups×time). Results were significant in the interaction (P ≤ 0.05). A significant F value was observed (F = 46.0, p = 0.000). A t-test for independent samples determined the differences between the groups. Probability-adjusted Student’s paired t-test was used for pair-wise comparisons. Test–retest reliabilities, as showed by ICC, ranged from 0.89 to 0.93 for all testing instruments. ICC reliabilities, as showed by ICC, ranged from 0.89 to 0.93 for all testing instruments. Results were significant in the interaction (P ≤ 0.05). After the training period, significant (p < 0.05) increases were observed in the EG in CMJ performance (40.2%) (Fig. 3), ball throwing distance (17.2%) (Fig. 4) and sprint time in 10 m (−14.3%) (Fig. 5). Significant main effects for time were observed on CMJ (−5.5%; −6.0%; −1.4%; −1.0%, respectively). Significant main effects for time were observed on 1RMBP (61.8%), 1RMLE (44.1%) (Fig. 1), dominant and non-dominant handgrip (5% and 6.9%, respectively) (Fig. 2), whereas no significant (or slightly decreased) changes were observed for the CG (−5.5%; −6.0%; −1.4%; −1.0%, respectively). Significant main effects for time were observed on 1RMBP, 1RMLE, HGd and HGnd, F = 31.6, 29.9, 6 and 11.3, respectively, p < 0.05. After the training period, significant (p < 0.05) increases were observed in the EG in CMJ performance (40.2%) (Fig. 3), ball throwing distance (17.2%) (Fig. 4) and sprint time in 10 m (−14.3%) (Fig. 5). Significant main effects for time were observed on CMJ, BT, S10m, F = 12.4, 25.7, 28.3, respectively, p < 0.05. The CG showed no significant improvements in these parameters. In both functional tasks, the EG showed significant improvements in performance after the training period, whereas significant declines were registered by the CG (Fig. 6). Significant main effects for time were observed on STS and GUG, F = 4.1, 9.6, respectively, p < 0.05. Significant group×time interactions were noted for all measures (p < 0.05), with the EG making significantly greater improvements in performance than CG. There were no significant interaction effects between groups on the GUG and BT, F = 0.7 and 1.8, respectively, (p > 0.05).

### Table 1

<table>
<thead>
<tr>
<th>Exercises (†)</th>
<th>Session 1</th>
<th>Session 2</th>
<th>Session 3</th>
<th>Session 4</th>
<th>Session 5</th>
<th>Session 6</th>
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<td>50% × 10 reps</td>
<td>50% × 10 reps</td>
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<tr>
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<td>2 × 5.15 kg</td>
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<td>2 × 5.15 kg</td>
<td>2 × 5.15 kg</td>
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<tr>
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### Table 2

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<th>Variables</th>
<th>Group</th>
<th>T1</th>
<th>p-value (T1 vs T2)</th>
</tr>
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<tr>
<td>Body weight (kg)</td>
<td>CG</td>
<td>66.2 ± 10.9</td>
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<td></td>
<td>EG</td>
<td>68.2 ± 11.2</td>
<td>68.6 ± 11.3</td>
</tr>
<tr>
<td>BMI (kg.m−2)</td>
<td>CG</td>
<td>27.0 ± 3.2</td>
<td>26.6 ± 2.9</td>
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<tr>
<td></td>
<td>EG</td>
<td>28.2 ± 4.0</td>
<td>28.4 ± 4.0</td>
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<tr>
<td>Total standing height (cm)</td>
<td>CG</td>
<td>1.57 ± 0.06</td>
<td>1.57 ± 0.06</td>
</tr>
<tr>
<td></td>
<td>EG</td>
<td>1.55 ± 0.06</td>
<td>1.55 ± 0.06</td>
</tr>
</tbody>
</table>

Legend: CG = Control Group; EG = Experimental Group; BMI = Body mass index, a weight-to-height ratio, calculated by dividing one’s weight in kilograms by the square of one’s height in meters; p-value (T1 vs T2) — statistical differences within each group between first and second evaluation (T1 and T2).
4. Discussion

The use of the upper and lower-body strength testing and training regimen is unique and provides interesting data in the context of training components for health-related fitness in older populations. The present findings demonstrated that 12 weeks of high-speed power training focused on explosive movement performance that is effective in enhancing strength, muscle power and function in older women.

The EG showed significant improvements in 1RMbp (61.8%) and hand-grip strength (dominant: 5%; non-dominant: 6.9%). In turn, the CG showed significant declines in their 1RMbp performance (−5.5%), while the maximal isometric handgrip strength remained unchanged (−1.4% and −1.0% in dominant and non-dominant hand, respectively). These results suggest a positive effect of strength training participation on upper body muscular strength in older women. Our findings agree with previous studies that reported relevant increases in muscle strength bench press following training programs of different time-length (from 10 to 24 weeks) (Izquierdo et al., 2005; Kalapotharakos et al., 2005).

In agreement with the present findings, the progressive high-speed power training showed improvements in handgrip isometric strength. Hand-grip strength has been described as a useful predictor of all-cause mortality in the older population and may serve as a convenient tool for prognostication of mortality risk in this age group (Shields et al., 1999). Ensrud et al. (1994) showed that a 5 kg reduction in grip strength is associated with an odds ratio of 1.5 for difficulty in performing three or more activities of daily living. Significant improvements were also observed in the upper limb ball-throwing performance. This agrees with previous studies showing that, in previously untrained older women, a three-week velocity training approach may be an optimal stimulus to induced explosive ball throwing gains in older women (Adams et al., 2001). According to our results, the current high-speed power training can be used to improve strength as well as to inhibit onset of disability. Furthermore, the inclusion of the ball throwing exercise could likely lead to isometric strength enhancement. Nevertheless, this type of training should be performed only by older people without muscle-skeletal injuries or risks.

Fig. 1. Maximal bilateral concentric one-repetition maximum (1RM) bench-press (a) and leg extension (b) at pre-training (T1) and after 12 weeks of training (T2). Values are means (±SD). *Significantly different (p<0.05) within each group between T1 and T2. $Significant changes (p<0.05) between CG and EG.

Fig. 2. Maximum isometric dominant hand (a) and non-dominant (b) at pre-training (T1) and after 12 weeks of training (T2). Values are means (±SD). *Significantly different (P<0.05) within each group between T1 and T2. $Significant changes (P<0.05) between CG and EG.

Fig. 3. Vertical jump (CMJ) at pre-training (T1) and after 12 weeks of training (T2). Values are means (±SD). *Significantly different (P<0.05) within each group between T1 and T2. $Significant changes (p<0.05) between CG and EG.
Training-induced increases of lower-extremity strength have been suggested as being important in decreasing functional limitations and disability in older populations. The present high-speed power training led to 1RMLE gains (44%). This value is comparable with recent studies on previously untrained women who have shown increases of 8–29% in 1RMLE after 8–24 weeks of strength training (Häkkinen et al., 2000; Earles et al., 2001; Holviala et al., 2006). In addition to the marked increases obtained in maximal dynamic strength of the leg extensor muscles, the present training program led to even more significant increases in muscle power output in the CMJ test score (40.2%). However, a unique finding of the present study was that training-induced gains in maximal strength and power were also related to muscle function enhancement (Caserotti et al., 2008). Walking velocity (S10m) improved by 14.3% (p=0.00) in the EG after the 12-weeks training but not in CG. Similar results were found in previous studies (Häkkinen et al., 2000; Beyer et al., 2007). We emphasize that the changes observed in our study result of high-speed power training are even more marked than changes found in other studies using different RT protocols (Sayers et al., 2003; Hanson et al., 2009). In the chair stand test (STS) the EG also increased performance by 17.7% (p=0.00). Thus, Henwood and Taaffe (2005) showed that a progressive RT incorporating high velocity exercises led to very significant improvements in chair stand time (p<0.05) and may thus be an aid in developing more independence.

A possible limitation of the present study was the absence of comparisons between different training programs, with groups that performed the traditional strength training (moderate to high intensity, only slow contractions) or endurance training, as a means of evaluating the specificity of each type of training. Thus, it is difficult to ascertain percentage gains among the various resistance training studies using older adults.

In summary, our study suggested that in older women high-speed power training is an effective, well-rounded exercise program that can be set up as a means to improve general strength and functional fitness in healthy older women. In addition, it is recommended that future research investigate interventions in older populations that not only have a significant role in increasing strength and power but also in increasing the concentric contraction velocity at which power is maximized.

4.1. Practical applications

Training program strategies aimed at improving quality of life in older individuals have become more important with the continuing growth of the aging population. The training program proposed here is a useful working tool for health and sports professionals, contributing to a better way of prolonging functional independence and quality of life. More periodization in the training program is needed to optimize training-induced increases in maximal strength and muscle power output in older women. The present observations may have important practical relevance for optimal construction of strength-training programs for middle-aged and older women, since muscle strength determines the ability to develop force rapidly and to proficiently execute daily tasks, such as climbing stairs and walking, so as to conserve effort and thus ultimately to prolong an independent lifestyle.

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