High-Speed Resistance Training in Elderly People: A New Approach Toward Counteracting Age-Related Functional Capacity Loss

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ABSTRACT

STRENGTH AND HIGH-VELOCITY MOVEMENTS ARE 2 ESSENTIAL CONDITIONS IN AGING HEALTH IMPROVEMENT AND MAINTENANCE. THIS ARTICLE PROVIDES A NEW APPROACH AND STRATEGIES FOR DEVELOPMENT OF STRENGTH AND POWER IN THE ELDERLY POPULATION.

INTRODUCTION

In the elderly, muscle strength is a main determinant in the performance of everyday tasks (1). Previous recommendations for resistance training (RT) in elderly people concluded that explosive exercises executed at 50–80% of the level of exertion are important to increase muscle performance (37). Combined progressive RT focused on explosive exercises has also been related to improvements in maximal strength (isometric and dynamic actions) and in power performance of the lower-body muscles in men and women of varying age ranges (15). The strength gains were accompanied by considerable increases in muscle mass as well as neuromuscular activation of the agonist muscles, with significant decreases relative to maximal antagonist coactivation in the experimental groups (15). Moreover, in certain studies, high-speed power training has been reported to enhance muscular performance and functional capacity in older adults (20,21,39). However, the loss of muscular contractions at maximal capacity may result in increased disability in carrying out daily tasks, for example, avoiding traffic and checking accidental forward falls (6). In this way, high-speed power training would appear more efficient in increasing strength and slowing muscular weakness in elderly populations (36).

Since the 90s, studies that focused on measuring age-related skeletal muscle changes. Isometric and dynamic strength and endurance tests were the main strategies used to observe differences between young and elderly women (20–80 years). Regardless of the growing interest of sport science coaches and conditioning

KEY WORDS: high-speed; power; elderly; women; functional capacity
specialists in this area, muscular performance still needs to be investigated in elderly populations. To our best knowledge, for example, few studies have evaluated changes in muscular performance and upper and lower extremity functionality in elderly women using higher velocity training. Moreover, very few experiments have examined RT interventions using high-velocity movements designed to improve not only muscle power in this population but also overall strength, velocity, and agility (15,48). Training programs focusing on high-velocity exercises are crucial to this segment of the population (36). Besides, traditional resistance programs seem only to enhance muscular strength and local muscular endurance relative to the type of strength exercise performed (26). This segment of the population may therefore need a different type of training program with specific exercises to increase strength and power performance plus the functional capacity necessary to maintain self-independence (39).

The present review will focus on supervised exercise programs that improved muscle strength and power output in the elderly. In addition to these effects of training, the present review will identify the most recommended training strategies, such as the volume, intensity, and weekly frequency, as well as side effects. High-speed training strategies to improve the muscle power output of elderly individuals will then be recommended based on the scientific literature.

LITERATURE SEARCH

SEARCH STRATEGY

The Scielo, Science Citation Index, MEDLINE, Scopus, Sport Discus, and ScienceDirect databases were searched from March to August 2012 for published articles based on original scientific investigations during the period from 1982 to 2012. The search terms included various combinations of the following keywords: “resistance training in older adults,” “explosive resistance training in older adults,” “power-training in older adults,” “muscle power in elderly,” “muscle strength in elderly,” “detraining in older adults,” “velocity training in older adults,” and “high-velocity resistance training in older adults.” The names of authors who were cited in some of the studies were also used in the search.

CRITERIA FOR STUDY CONSIDERATION

The search criteria were as follows: (a) the studies must have been published in English, peer-reviewed, scholarly journals; (b) dissertations, theses, and conference proceedings were excluded; (c) the studies must have mentioned the effects of exercise training programs, such as strength, power, and explosive development in elderly; and (d) detailed information about the exercise interventions and the control group must have been provided. The control group must not be physical activity group. Exceptions were made in the studies comparing 2 different exercise interventions.

Data on exercise interventions that were associated with hormonal treatments, drug therapy, or other supplements were excluded. Thus, only the results of the exercise interventions were considered and are described in this review.

STRENGTH DEMANDS IN THE ELDERLY

Aging has been related with muscular atrophy and decreased functional performance, reducing the ability to perform daily tasks (1,5,20,21). Furthermore, a slowed capacity for high-velocity movements and delayed responsiveness to accidental falls in the lower and upper limbs are associated with disability and are a significant cause of injury (36). In therapeutic developments in elderly population, there is a potential role to increase muscle power focus on high-speed power training (4,11). Researchers in this area agree that RT can promote the elderly maximal strength and power output, decreasing the risk of muscle damage and contributing to increased autonomy in the performance of daily activities.

STRENGTH AND POWER TRAINING DEVELOPMENT

The current American College of Sports Medicine recommendations for older adults (2) for the enhancement of maximal strength prescribe slow-velocity repetitions for a maximum of 3 sets per exercise with 60–80% of 1 repetition maximum (1RM) for 8–12 repetitions (reps) and for increasing power guidelines include 1–3 sets per exercise using high velocity at 30–60% of 1RM for 6–10 reps. However, these guidelines are frequently found in studies that involve older subjects with varying health problems and assessment protocols.

Using training programs of variable intensity and different methods (sample size and age of the participants) can increase the discrepancy between studies and problematize the reproducibility of the data (29). A meta-analysis (17) and a review (29) reported that RT can positively affect strength (7) and power in leg extensors (rising from a chair and gait speed) but suggested only a moderate increase in other aspects of muscle functionality in lower extremities (44). However, exercise prescriptions vary considerably and experienced levels of physical activity tend to be more variable with increasing age.

Tables 1 and 2 summarize 19 studies focused on RT designed to increase maximal strength in older populations based on high-speed training. Sample sizes ranged from 7 to more than 110 participants. These studies vary, but the exercise prescriptions for developing maximal strength showed few substantial differences. Most included exercises for the lower limbs (knee extensor or leg press) and training frequencies varied from 1 to 3 days per week. It seems that intensity had the greatest effect, varying from moderate to high (40–80% of 1RM), 3–6 sets of 4–10 reps. Duration was revealed to have a much smaller effect on strength, because previous research has shown the efficacy of RT over durations ranging from 8 to 18–24 weeks and up to 1 year (52 weeks) (45). However, a 12-week period would appear to be usual. Muscular strength improvements between 4 and 70% were observed during the studies, varying in different age ranges.

Although some studies characterize the physical state of the participants, the strength gains and strategies were not
discriminated for those elderly having limitations of the muscular system or other clinical status that constrained the execution of all the exercises. Older populations with no experience in strength training were better to begin at low intensities to promote better adaptation, adherence, and technique, reducing the risk of injury (14).

**EXPLOSIVE DEVELOPMENT**

During maximal dynamic activities, it is usual to observe a decrease in the velocity of contractions according to the increment of external load. The relationship between force and velocity occurs approximately at 30% for peak isometric force (32), and between 30 and 50% of maximal strength (20,21). For the maximization of mechanical power output, our investigation with older women (36) recommended resistances in the range of 40–60% and 60–75% of 1RM for upper and lower extremity muscles, respectively. Results were not unique and therefore not in disagreement with other studies (6,21,39), with significant increases in dynamic and isometric strength performance (57–61%), muscle power (range, 14–40%), and function (range, 13–18%). However, no previous study, except for one recently published by our laboratory (36), has to date been undertaken with an older group of women. Moreover, to achieve significant gains in power performance, the external load needs to be specific to the type of training (31) as observed by Kaneko et al. (25).

<table>
<thead>
<tr>
<th>Studies</th>
<th>Subjects</th>
<th>Resistant training intervention</th>
<th>Significant improvement in muscle function</th>
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</thead>
<tbody>
<tr>
<td>Charette et al. (7)</td>
<td>Women (n = 27), age 68–70 y</td>
<td>6 sets, 6 reps at 75% 1RM, for 12-week LP and KE exercise</td>
<td>Significant gains of 28–93% in LP and KE strength</td>
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<tr>
<td>Nichols et al. (35)</td>
<td>Women (n = 36), age 61.6–67.8 y</td>
<td>AE 3 d/wk for 24 wk, RT (n = 18): 3 sets, 8 reps at 80% 1RM; 7 exercises for major muscle groups of trunk and upper and lower body</td>
<td>Significant strength increases for all exercises (5–65%), with the greatest gains in the shoulder and trunk muscle strength</td>
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<tr>
<td>Skelton and McLaughlin (44)</td>
<td>Women (n = 40); age 76–93 y</td>
<td>EX (n = 20): 1 session (1 h) and 2 unsupervised home sessions per week for 12 wk; 3 sets of 4–8 reps of each exercise, using rice bags (1–1.5 kg) or elastic tubing</td>
<td>Significant improvements in IKES (27%), IEFS (22%), HGS (4%), LEP/kg (18%), LEP (18%, p = 0.11) was not statistically significant</td>
</tr>
<tr>
<td>Jozsi et al. (24)</td>
<td>Men and women (n = 17); age 56–66 y</td>
<td>3 sets, 8–12 reps, at 80% 1RM, 2-3/wk; KE and arm pull exercise</td>
<td>Significant gains of 10–26% in KE and arm pull power as measured by a pneumatic resistance machine</td>
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<tr>
<td>Taaffe et al. (45)</td>
<td>Women (n = 7); age 65–79 y</td>
<td>HI group: 3 sets, 7 reps at 80% 1RM; LO group: 14 reps at 40% 1RM; both groups trained 3 d/wk for 52 wk; LP, KE, and KF</td>
<td>Significant strength increases of 59.4–41.5% for HI and LO, respectively, compared with 1.3% in CG</td>
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<tr>
<td>Izquierdo et al. (21)</td>
<td>Men (n = 11); age 64 y</td>
<td>RT, 3–4 sets, 8–15 reps, 50–80% 1RM, high-velocity movements, 2-3/wk for 16 wk</td>
<td>Significant power gains of 21–37% in KE, half squat, and BP</td>
</tr>
<tr>
<td>Earles et al. (10)</td>
<td>Older volunteers, age of 70 y</td>
<td>PT: high-velocity leg exercises 3/wk with weekly increases in resistance combined with 45’ of moderate, nonresistance exercise weekly; WG: moderate-intensity exercise 30 min daily, 6/wk</td>
<td>PP 22% (p = 0.004) in the PT group (3.7 ± 1.0–4.5 ± 1.4 W/kg) but did not change in the WG; LEP at resistance of 50, 60, and 70% of body weight increased 50, 77, and 141%, respectively, in the PT (p &lt; 0.0001); strength improved 22% in the power-trained individuals and 12% in the walkers (p &lt; 0.0001)</td>
</tr>
</tbody>
</table>

AE = aerobic exercise; BP = bench press; CG = control group; EX = exercise group; HGS = handgrip strength; HI = high-intensity training; IEFS = isometric elbow flexor strength; IKES = isometric knee extensor strength; KE = knee extension; KF = knee flexion; LEP = leg extensor power; LO = low-intensity training; LP = leg press; PP = peak power; PT = power training; reps = repetitions; RT = resistance training; sets = series; WG = walking group; 1RM = 1 repetition maximum.
Table 2
RT studies designed to improve power in elderly (2002–2012)

<table>
<thead>
<tr>
<th>Studies</th>
<th>Subjects</th>
<th>Resistant training intervention</th>
<th>Significant improvement in muscle function</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fielding et al. (12)</td>
<td>Women (n = 30); age 73 y</td>
<td>HI and LO RT, 3 sets, 8–10 reps at 70% 1RM, 3/wk for 16 wk; LP exercise.</td>
<td>HI resulted in a 97% power gain in LP compared with 45% power gain with LO. Both gains were significant.</td>
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<tr>
<td>Hruda et al. (18)</td>
<td>Men and women (n = 25); age 75–94 y</td>
<td>EX (n = 18) using lower-body resistance exercises, 3/wk, 10 wk; the CG (n = 7) maintained their usual daily activities.</td>
<td>Significant increases were found in the EX group for eccentric (44%) and concentric (60%) average power (p &lt; 0.05) and in 8-ft up-and-go timed test, 30-s chair stand, and 6-m walk timed test; improved by 31, 66, and 33%, respectively (p &lt; 0.05).</td>
</tr>
<tr>
<td>Miszko et al. (33)</td>
<td>Men (n = 17) and women (n = 22); age 65–90 y</td>
<td>CG (n = 15), ST (n = 13), or PT (n = 11) groups; RT: 3 sets, 6–8 reps at 50–70% 1RM between 1 and 8 wk, 80% 1RM for weeks 9–16; PT: first 8 wk same as ST to build base; 3 sets, 6–8 reps, as fast as possible for weeks 9–16; ST and PT: 3 d/wk for 16 wk.</td>
<td>PT and ST did not differ in LP or chest press 1RM. PAP did not differ among groups.</td>
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<tr>
<td>De Vos et al. (9)</td>
<td>Men and women (n = 112); age 69 y</td>
<td>Explosive RT, 3 sets, 8 reps at 20, 50, and 80% 1RM, 2 d/wk, 8–12 wk; 5 explosive exercises.</td>
<td>FPP increased significantly over time. Average changes in FPP were 16, 13, 12, and 2% in the groups training at 80, 50, 20%, and control, respectively.</td>
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<tr>
<td>Henwood and Taaffe (16)</td>
<td>Healthy community-dwelling adults aged 60–80 y</td>
<td>3 groups: EX (n = 15) or maintained customary activity (CG: n = 10) for 8 wk; the EX group trained 2/wk using machine weights for 3 sets of 8 reps at 35, 55, and 75% of their 1 RM for 7 upper- and lower-body exercises using explosive concentric movements.</td>
<td>Dynamic muscle strength significantly increased (p = 0.001) in the EX group for all exercises (from 21.4 ± 9.6% to 82.0 ± 59.2%, mean ± SD) after training, as did knee extension power (p &lt; 0.01). Significant improvement occurred for the EX group in the floor rise to standing (10.4 ± 11.5%, p = 0.004), usual 6-m walk (6.6 ± 8.2%, p = 0.010), repeated chair rise (10.4 ± 15.6%, p = 0.013), and lift and reach (25.6 ± 12.1%, p = 0.002) performance tasks but not in the CG group.</td>
</tr>
<tr>
<td>Katula et al. (27)</td>
<td>Men (n = 15) and women (n = 30); age 74.8–6.5.7 y</td>
<td>PT, ST, or CG groups (n = 15 per group). PT and ST did 3 sets, 8–10 reps at 70% 1RM, 3/wk for 12 wk; lower- and upper-body exercises.</td>
<td>Both the PT and ST groups had significant gains in KE and LP strength as well as lower extremity muscle power over baseline.</td>
</tr>
<tr>
<td>Sayers (40)</td>
<td>Men (n = 3) and women (n = 9); age 74.6–6.1.9 y</td>
<td>HV (n = 5): 40% 1RM; LV (n = 4): 80% 1RM or CG (n = 3); HV: 3 sets, 12–14 reps, concentric phase as fast as possible; LV: 3 sets, 8–10 reps; LP and KE exercise, pneumatic equipment.</td>
<td>STR had a bigger improvement in 1RM (21%) compared with HV (14%). HV training improved peak power (19–28%) and improved strength as well (9–22%). FPP improved more for STR (16–24%) than for HV (11–14%).</td>
</tr>
</tbody>
</table>
In addition, the preservation of strength and power parameters during the DT period in older women once the training intervention has ended (12,13). This may partly explain the discrepancy of results between studies. Methodology plus the individual characteristics of elderly people can produce dissimilar results (39).

As Kraemer et al. (28) concluded, jump performance can be maintained in trained men after the cessation of training (6 weeks). It seems that the learning effect that jumping technique may induce helped in that instance to underpin the results during the DT period. Pereira et al. (36) found that a short-term DT led to larger effects in maximal strength (18.1–23.8%) of both upper and lower extremity muscles than in muscle power (2–4.5%) and function (2.8%). However, all measurements remained higher (12.6–36.4%) than for the pretraining levels.

**Table 2 (continued)**

<table>
<thead>
<tr>
<th>Study</th>
<th>Age</th>
<th>Intervention</th>
<th>Results</th>
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<tbody>
<tr>
<td>Nakamura et al. (34)</td>
<td>Women (n = 45); age 62–72 y</td>
<td>I, II, and III groups: n = 34 and CG: n = 11.</td>
<td>The greatest improvements in body fat, muscular endurance, and dynamic balance were observed in group III (p &lt; 0.05). However, no significant differences were found in muscular strength.</td>
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<tr>
<td></td>
<td></td>
<td>I: 90’ exercise, 1 d/wk for 12 wk; II: 2 d/wk for 12 wk; and III: 3 d/wk for 12 wk; RT: 10‘ warm-up, 20‘ walking, 30‘ recreational activities, 20‘ of RT (3 sets of 10 reps), and a 10‘ cooldown.</td>
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<td>Caserotti et al. (6)</td>
<td>Women randomized into 2 groups: age 60–65 y and very old, 80–89 y (TG60 and TG80, respectively)</td>
<td>Explosive-type heavy RT (75–80% of 1 RM), 12 wk; maximal intentional acceleration during the concentric phase.</td>
<td>RFD, impulse, and MVC increased by 51, 42, and 28% in TG80 and by 21, 18, and 18% in TG60, respectively. CMJ increased by 18 and 10% in TG80 and TG60, respectively, whereas jump peak power increased in TG60 (5%). Finally, LEP increased 28% in TG80 and 12% in TG60.</td>
</tr>
<tr>
<td>Sayers and Gibson (42)</td>
<td>Men and women (n = 38); age 70–75 y</td>
<td>Two groups: high-speed power training at 40% of the 1RM, 12 wk and RT at 80% 1RM and a CG.</td>
<td>Speed-related muscle performance (PP velocity and overall HV) was most positively impacted by high-speed power training.</td>
</tr>
<tr>
<td>Pereira et al. (36)</td>
<td>Women (n = 56); age 60–67 y</td>
<td>EX (n = 28) was submitted 12 wk to high-speed power training that consisted of 40–75% of 1 RM; 3 sets of 4–12 reps, CMJ, and medicine ball (1.5 kg) throwing. CG did not perform any exercise.</td>
<td>Significant improvements in dynamic and isometric strength performance (57–61%), muscle power (range, 14–40%) (p &lt; 0.05), and function (p &lt; 0.05).</td>
</tr>
</tbody>
</table>

CG = control group; CMJ = countermovement jump; EX = exercise group; FPP = force at peak power; HI = high-intensity training; HV = high-velocity resistance training; KE = knee extension; LEP = leg extensor power; LO = low-intensity training; LP = leg press; LV = low-velocity resistance training; MVC = maximal voluntary contraction; PAP = peak anaerobic power; PP = peak power; PT = power training; reps = repetitions; RFD = rate of force development; RT = resistance training; sets = series; ST = strength training; STR = low-velocity RT; 1RM = 1 repetition maximum.

**POWER ACQUISITION VERSUS DETRAINING**

Elderly adults often experience pauses and interruptions in regular training sessions (19,30) as a result of family considerations, disease, or other factors that can cause a decrease or termination of their normal physical activity (5,16). Moreover, the length of cessation (22) may influence the physical levels achieved during the period of training (36,47,49). Little is known about the regressive effects of a detraining (DT) period in older women once the training intervention has ended (12,13). This is important, given that we are finding that targeted interventions specific to age, gender, and capacity have greater value than a one-size-fits-all model (39).

In addition, the preservation of strength and power parameters during the DT period can be affected by the maintenance of daily tasks and whether the period of DT is too short to observe significant changes in muscular performance. This may partly explain the discrepancy of results between studies. As Kraemer et al. (28) concluded, jump performance can be maintained in trained men after the cessation of training (6 weeks). It seems that the learning effect that jumping technique may induce helped in that instance to underpin the results during the DT period. Pereira et al. (36) found that a short-term DT led to larger effects in maximal strength (18.1–23.8%) of both upper and lower extremity muscles than in muscle power (2–4.5%) and function (2.8%). However, all measurements remained higher (12.6–36.4%) than for the pretraining levels.

**PROGRAM DESIGN RECOMMENDATIONS FOR ELDERLY ADULTS**

Maximal strength and power increase in elderly adults requires specifically designed resistance programs. Moreover, it is crucial to focus the resistance exercise intervention not only on the improvement of performance but also on the increase and preservation of health: to increase maximal strength and power in upper and lower extremity muscles and to improve total balance especially in the lower limbs. Nevertheless, the design of RT may depend on the specific category and muscular condition of the elderly adult in question.

An example of an RT program designed for elderly populations might consist of 2–3 sessions per week performed during 12–16 consecutive weeks. It has been reported that a progressive RT program performed over 2 sessions a week...
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combined with explosive exercises, can increase strength and power performance of the leg extensor muscles in men of different ages (21).

It has been suggested that a progressive high-speed power training program that includes explosive actions may increase maximal strength, power output, and functional capacity of the upper and lower extremity muscles in older women over 3 sessions a week (36). The exercise program should always be monitored by sports science specialists to ensure that the elderly subjects perform the training plan in precise detail. A 10-minute warm-up may be useful and may include walking and articular mobilization exercises, before traditional exercises such as bench press and leg extension start.

As indicated in Pereira et al. (36), participants performed, over 12 weeks, 3 sets of each exercise with 4–10 reps with a minimal load of 40–75% of 1RM in bench press and leg extension. Program training included 2 power exercises (countermovement jump and the medicine ball throwing [1.5 kg]). Participants were instructed to perform all the exercises as fast as they were able to.

PRACTICAL APPLICATIONS

As life expectancy increases, it is becoming crucial to implement high-speed power training strategies or a specific well-designed training program for elderly populations capable of enhancing functional capacity to increase and maintain autonomy and independence. Aggregating muscle strength, power, and functional task measures across the natural life of women will be important for young people and will doubtless shape the development of future studies.

To address this task, future programs of RT in older women must make use of rigorous designs plus assessment tests to evaluate disability and monitor these with specialized professionals. Appropriate training programs must also be planned, to provide for different participants, particularly those with preexisting functional limitations and disabilities in the home. Care must be taken when implementing these types of training program and exercise regimens in medically fragile populations because not all studies report the incidence of resultant injuries and adverse events.

Conflict of Interest and Source of Funding: Supported in part by the Spanish Department of Health and Institute Carlos III of the Government of Spain (Spanish Net on Aging and frailty: RETICEF), Department of Health of the Government of Navarre, and Economy and Competitivity Department of the Government of Spain, under grants numbered RD12/0043/0002, 87/2010, and DEP2011-24105, respectively. This project is also funded in part by the European Commission (FP7-Health, Project reference: 278803).

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