REVIEW / SYNTHÈSE

Power training for older adults

Michelle M. Porter

Abstract: Resistance training is widely advocated for older adults to alleviate the muscle and strength loss that occurs with aging. While primary and secondary prevention of disability are often mentioned as benefits of strength training, the evidence for this is limited and inconclusive. Researchers have started to examine another form of resistance training that may prove to be more beneficial than strength training in terms of the reduction of age-related disability. Power training is being investigated because several studies have shown a stronger relationship between power and function than between strength and function. Early studies on power training suggest that neuromuscular power can be increased to a greater extent with high velocity or explosive training than strength training alone. In addition, there may be more positive effects on performance tasks measured in the laboratory, although evidence on disability reduction was very limited. Adverse events were reported in several studies, although the risk for injuries appears to be higher for testing than for training itself. Future well-designed studies on the risks and benefits of power training should provide more evidence on this promising form of resistance training for older adults of varying health and functional status.

Key words: aging, resistance training, physical activity, physical function.

Résumé : On recommande souvent aux personnes âgées l'entraînement à la force pour minimiser la fonte musculaire et la diminution de la force qui accompagnent le vieillissement. Même si on reconnaît l'entraînement à la force comme mode de prévention primaire et secondaire de l'incapacité physique, il y a peu d'études scientifiques sur ce thème et elles sont non concluantes. Les chercheurs analysent depuis peu une autre forme d'entraînement à la force qui semble plus prometteuse au chapitre de la réduction des incapacités physiques. Comme on a observé dans plusieurs études une meilleure relation entre la puissance et la fonction qu'entre la force et la fonction, l'entraînement en puissance fait l'objet d'études. Les premières études sur l'entraînement en puissance indique une plus grande augmentation de la puissance neuromusculaire au cours d'un entraînement à haute vélocité ou explosif qu'au cours d'un entraînement à la force seule. De plus, on peut observer plus d'effets positifs sur des tâches à réaliser en laboratoire malgré le peu d'information solide sur la réduction des incapacités. Des études ont rapporté des effets indésirables même si le risque de blessure semble plus élevé en situation de testing qu'à l'entraînement en soi. Des études mieux structurées sur les risques et bénéfices de l'entraînement en puissance devraient nous procurer plus d'évidence au sujet de cette forme prometteuse d'entraînement à la force chez des individus âgés à l'état de santé varié et aux capacités fonctionnelles diverses.

Mots clés : vieillissement, entraînement à la force, activité physique, fonction physique.

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Introduction

Resistance training is now widely recommended for older adults, for the sake of muscle mass, strength, and, ultimately, independence (American College of Sports Medicine 1998*b*; Health Canada 1999). The purpose of this short review is to specifically review a newer form of resistance training — power training — that has potential benefits, particularly improvement of functional performance of daily activities.

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Background information on resistance training for older adults

Resistance training has been explored scientifically for a number of decades, beginning with the research of DeLorme in the 1940s (Delorme 1945). Resistance training for older adults specifically was studied sporadically between the 1960s and the 1980s, initially with the work of Perkins and Kaiser (Perkins and Kaiser 1961). Many of these studies used relatively low intensities of training or mostly involved calisthenics primarily among male subjects (see Porter and Vandervoort 1995 for a review of these early studies).

Resistance training can be done in a number of different ways depending on the physiological and functional or performance goals. The different trainable characteristics of the neuromuscular system include strength, endurance, power, muscle hypertrophy, and motor performance (Kraemer et al.

2002). Because different facets of the neuromuscular system are involved to different extents for each of the above characteristics, training must be specific.

In 1980, it was thought that resistance training for older adults would only be beneficial for neural adaptations and that older muscle was unable to hypertrophy (Moritani and DeVries 1980). In the next decade, very little further research was done on resistance training for older adults. This changed with the seminal studies of Frontera et al. (1988) and Fiatarone et al. (1990). It was clearly established by more sophisticated imaging techniques (i.e., computed tomography) in these studies that older adults, even the very elderly in nursing homes (Fiatarone et al. 1990), could achieve muscle hypertrophy (9.0% ± 4.5%) with short-term (8–12 weeks), high-intensity training. Following these studies there was an explosion of research, with literally hundreds of studies being conducted on resistance training for older adults. Because aging can lead to tremendous amounts of atrophy (i.e., sarcopenia) resulting in weakness, the main emphasis of these training programs was improving strength and achieving muscle hypertrophy (see Porter 2001 for review). Therefore, the mode of training was usually high-intensity resistance training following the form of 8–15 repetition maximums (RMs) for 1–3 sets, which became the recommendation from the American College of Sports Medicine (American College of Sports Medicine 1998*a*). A recent systematic review of well-designed studies substantiated that strength training is effective in increasing strength and hypertrophying muscle, with high-intensity training being more effective than low-intensity training (Latham et al. 2004). Additionally, modest improvements have been found in gait speed, time to stand from a chair, and walking endurance (Latham et al. 2004).

Recently, some have asked the question, “Have we oversold the benefit of late-life exercise?” (Keysor and Jette 2001). These authors argue that while exercise and physical activity have been found to be very beneficial for the prevention and treatment of several conditions, and indeed many aspects of physical fitness can be improved in older adults with exercise programs, the evidence for reducing disability in older adults is extremely limited or nonexistant (Keysor and Jette 2001; Keysor 2003). Latham and colleagues, in their systematic reviews of strength training for older adults, have also come to the conclusion that the research is lacking in the area of disability reduction (Latham et al. 2003; Latham et al. 2004). Some of the methodological failings of the studies reviewed (Latham et al. 2004; Keysor and Jette 2001) include the following: (*i*) they have a relatively small number of participants, (*ii*) they neglect to measure disability, (*iii*) they necessity that resistance training be combined with other forms of training to have effects on function, (*iv*) a relatively short duration of trials, (*v*) the disability scales used may not be responsive to change, and (*vi*) other non-physiological factors alike self-efficacy or behaviour modification have not been examined. Another issue recently studied by many authors is the specific form of resistance training.

While strength is important, power has been found to be more relevant for many tasks of daily living (Bassey and Short 1990; Bassey et al. 1992; Foldvari et al. 2000) and has been associated with mortality (Metter et al. 2004). In addition, power has been found to decrease at a much greater rate than strength (Metter et al. 1997). Part of the explanation for the loss of power with age is the muscle atrophy that occurs; however, since power also incorporates speed of movement, the quality of the remaining muscle in terms of its slower contractile properties is certainly another factor (Vandervoort and McComas 1986). Because there is a greater atrophy of type II fibres with aging (Lexell et al. 1988) and because type II fibres have much greater power-generating capabilities than type I fibres the functional impairments of the neuromuscular system go beyond muscle atrophy alone.

To improve power, different types of resistance training programs may have to be considered. Whereas programs aimed at increasing strength or using strength-training regimens have been found to increase power (Skelton et al. 1995; Jozsi et al. 1999), resistance-training programs specifically designed to enhance power (Kraemer 2002) may be more effective at improving power and potentially reducing disability (Evans 2000).

Power training

Power is defined as work (force × distance) divided by time, whereas strength is the ability to produce force. Therefore, power is a “function of both strength and speed and is exhibited by producing high forces very rapidly” (Weir and Cramer 2006). Typical strength-training repetitions involve a considerable amount of deceleration and thus may actually decrease power output (Kraemer et al. 2002). To overcome this, movements should be performed with explosive action. Although several different types of exercises, such as Olympic style lifts or plyometrics using medicine balls, could be performed to increase power, they are more suitable for the athlete or experienced weight lifter, not for an inexperienced older adult. To increase power, the ACSM position stand on progression in resistance training (Kraemer et al. 2002) recommends that healthy older adults perform 1–3 sets using light to moderate resistance (40%–60% 1RM) for 6–10 repetitions with high velocity, progressing from machine-based to free weights. Since this position stand was first published, more evidence has become available on power training for older adults. Studies have now been conducted to examine the effects on function, as well as to identify the most beneficial load. In addition, more evidence is available on the risks associated with power training.

Power training for older adults

Since the late 1990s, several studies have been done to examine the effects of power training (see Table 1). The initial studies on incorporating explosive-type movements into resistance training for older adults generally involved relatively healthy older men and (or) women who were already physically active (Hakkinen and Hakkinen 1995; Hakkinen et al. 1998, 2001*a*, 2001*b*; Izquierdo et al. 2001). All of these studies combined traditional strength-training regimes (progressive high-intensity overload but low velocity) with explosive actions for part (20%) of the workout sessions. They found that older individuals could undertake power-type training and achieve several physiological benefits. Of course, one of the most important benefits was an increase in rapid force production capabilities. The improvements were partly explained by increases in muscle cross-sectional area at the whole muscle (Hakkinen et al. 1998) and muscle fibre levels (Hakkinen et al. 2001*a*), but were mostly explained by neural adaptations (Hakkinen et al. 1998). The neural adaptations included greater activation of the agonists and less antagonist coactivation (Hakkinen et al. 1998). Interestingly, middle-aged and older women seemed to be more hypertrophically responsive to the training program than men (Hakkinen et al. 2001*a*), even though these authors have reported that low levels of testosterone may limit muscle hypertrophy with resistance training in older women (Hakkinen et al. 2001*b*). Although many training-induced physiological changes were noted with the combined strength and power training, these studies did not address changes in function of their physically active subjects, nor did they determine whether power training was more effective than traditional strength training.

Low- vs. high-velocity training

Differences in gains in power depending on the type of training were directly addressed in a few studies. Signorile et al. (2002) compared training differences between low- and high-speed paradigms on an isokinetic dynamometer. For knee flexors and extensors, high-speed training was done at a rate of rotation of 280°/s; for the ankle plantar and dorsiflexors, the rate was 180°/s. For all muscle groups, low-speed training was done at 60°/s. The effects were found to depend on the muscle group examined and it was suggested by the investigators that upper leg and lower leg training regimes might need to be different, in that the thigh muscles appeared to benefit more from power training than the plantar or dorsiflexors. However, this result may be due to the fact that the isokinetic speeds actually attained during lower leg training may not have been sufficient to elicit a training stimulus. The authors state that high speed training of the ankle musculature may have been affected by the very short time frame during which subjects were actually at the prescribed 180°/s during the training repetitions. Therefore, whether or not there are any “joint-specific exercise prescriptions targeting speed and power in older persons” (Signorile et al. 2002) remains to be determined.

Mizsko et al. (2003) specifically compared power training to strength training. Gains were seen to be specific to the type of training, i.e., power trainers increased power to a greater extent, whereas strength trainers increased strength more. In this study, the power-training group switched to power training (3 sets at 40% 1RM as fast possible, 1 s/concentric contraction) after their base of 8 weeks of strength training (50%–70% 1RM with 4 s for each concentric contraction).

Fielding et al. (2002) did not find differences between their low-velocity and power-training groups for strength improvements. This was expected because the strength and power training were designed to have similar intensities (70% of 1RM) and the same amount of external work. They also progressed the groups according to strength gains and not power gains. The main difference between the groups’ training was the speed of the concentric contractions, with the high-velocity group completing them in 1 s and the low-velocity group performing the contractions over 2 s, with a pause between the concentric and eccentric phases. In terms of power changes, they did show that overall high-velocity training was more effective in eliciting improvements in power, which was particularly true at submaximal intensities (40%–90% 1RM). Leg press power did improve to a greater extent than knee extension power, even in the power training group, which was attributed to the differential power outputs achieved in the training sessions. While these studies seem to suggest that power training is more effective than strength training for improving power, is power training effective in improving function and reducing disability?

Effects of power training on function

Earles and colleagues (2001) conducted the first power-training study to examine changes in both fitness and function. High-functioning men and women over the age of 70 participated in the 3-month-long study, which randomized the subjects into a power-training group and a walking group. The power trainers performed leg press (progressing to 70% 1RM over the 12 weeks) and other leg exercises with a weight belt (step ups, chair raises, and hip and plantar flexion). The program gradually progressed so that the subjects were performing all exercises at high velocity, which was instructed to be “as fast as you can”. Power training resulted in modest strength gains (22%) and large power gains (150% at 70% of body mass), whereas the walkers made only small changes. Likely owing to ceiling effects, no changes were seen in function. In this study, “exclusion criteria were designed to reduce the risk of injury”, as it was a preliminary study involving this type of training, so subjects scored well at baseline on tests of function and therefore had little room for improvement in these variables.

Later studies specifically recruited individuals with impaired function living in the community, as well as those in the long-term care setting (Sayers et al. 2003; Hruda et al. 2003; Miszko et al. 2003; Bean et al. 2004; Kongsgaard et al. 2004); at the very least, they did not exclude individuals with poor physical function (Henwood and Taaffe 2005). All of these studies reported improvements with physical testing as a result of power training (see Table 1). Specific tests that were affected positively over and above changes seen in a control group (if applicable) included stair-climbing speed (Sayers et al. 2003; Kongsgaard et al. 2004), balance (Sayers et al. 2003), gait speed (Hruda et al. 2003; Kongsgaard et al. 2004), (Henwood and Taaffe 2005), chair stand (Bean et al. 2004; Henwood and Taaffe 2005), floor rise to stand (Henwood and Taaffe 2005), lift and reach (Henwood and Taaffe 2005), and whole-body physical function (Miszko et al. 2003). Many of these same studies also reported several functional parameters that either did not change (Sayers et al. 2003) or did not change to a greater extent than in the control group (Hruda et al. 2003; Bean et al. 2004; Henwood and Taaffe 2005).

Although these studies were successful in improving the functional performance of a number of different tasks, were they more successful than has been found in more traditional strength-training studies? Two of these studies compared groups who undertook low-velocity (traditional) strength training with those undergoing power training (Sayers et al.

Table 1. Summary of studies that have examined power training.

Study	Subjects (*n*, age, controls, etc.)	Type of training	Length of training (months)	Measurements	Results
Hakkinen and Hakkinen 1995	10 M, 64–73; 11 W, 66–73; no controls	KE; strength + power	3	Strength, EMG; rate of force production, CSA	↑Strength, ↑CSA, ↑RFP, ↑EMG
Hakkinen et al. 1998	11 M, 72±3; 10 W, 67±3; no controls	Leg press, KE; strength + power	6	Strength, EMG; rate of force production, CSA	↑Strength, ↑CSA, ↑RFP, ↑EMG
Hakkinen et al. 2001*a* (same study as above)	11 M, 72±3; 10 W, 67±3; no controls	Leg press, KE; strength + power	6	Muscle fibre changes	↑CSA of type I and II fibres in W
Hakkinen et al. 2001*b*	10 W, 64±3; no controls	Leg press, KE; strength + power	5	Strength, EMG; rate of force production, CSA (whole and muscle fibre), hormones	↑Strength, ↑CSA, ↑RFP, ↑EMG, basal concentration of testosterone related to gains in CSA, ↑GH acutely
Izquierdo et al. 2001	11 M, 64±2; no controls	Leg press, KE, bench press, chest press, lateral pull-down, shoulder press, abdominals, trunk, standing leg curl	4	Half squats 1RM and power, KE, KF, bench press, thigh CSA, hormonal changes	↑Strength, ↑power, ↑CSA, %fat, serum cortisol, free testosterone
Earles et al. 2001	43 M+W, 78±5; no controls	Leg press, KE, HE, PF, HF high-velocity + functional training; walking group	3	Leg press power; KE strength, balance, chair rise, 8-ft walk, single leg stance, 6 min walk	↑Strength, ↑power; no change in physical function
Signorile et al. 2002	24 W, 61–75; *n* = 7 placebo controls	KE, KF, DF, PF; low- vs. high-velocity vs. control	3	Power at 1.05, 3.14, 4.73, 5.24 rad/s	↑DF power from low- and high-speed training, ↑ PF power with low-speed training, KE power ↑ at moderate and high speeds, ↔KF
Fielding et al. 2002	25 W, 73±1, impaired functioning, no controls	Leg press, KE; low vs. high velocity	4	Strength; power	↑Strength same for both groups; power ↑ greater for high- than low-velocity training
Sayers et al. 2003 (same study as above)	25 W, 73±1	Leg press, KE; low vs. high velocity	4	Balance, chair stands, stair climb, gait speed, self-reported disability	Improved balance, ↔ chair rise, ↑stair climb speed, ↔gait speed, some improvements in self-reported disability measures; no differences between groups in improvements for any measure
Hruda et al. 2003	18 M+W, 84.9±4.8; controls (*n* = 7)	Body weight and bands (gradually performed more quickly)	2.5	KE strength + power, 8-ft up and go, chair stand, 6 m walk	↑Strength, ↑power, Change in power related to change in the functional tests; controls ↔
Miszko et al. 2003	39 M+W, 65–90; controls (*n* = 15)	Upper and lower body, 8 forms; low vs. high velocity	4	Strength, physical function, anaerobic power	Improvement in physical function greater in the power trainers; ↑strength both groups, no change in anaerobic power

Table 1 (*concluded*).

Study	Subjects (*n*, age, controls, etc.)	Type of training	Length of training (months)	Measurements	Results
Bean et al. 2004	10 W, >70; controls (*n* = 11); impaired functioning	Body weight plus weighted vest performed quickly	3	Leg press strength and power, 2.4m walk, balance, chair stand	Greater change with power training than placebo control for leg power and chair stand
Kongsgaard et al. 2004	9 M, 65–80 years with COPD; control M COPD patients (*n* = 7), breathing exercises, non-supervised	Leg press, KE, KF	3	CSA; isometric and isokinetic KE PT; leg press, trunk extension, KE power; gait speed; stair climbing; self-reported ADLs	↑Strength, ↑power, ↑CSA, ↑gait and stair climbing speed, improvements in self-reported ADL; controls↔
Henwood and Taaffe 2005	15 M+W, 69.9±6.5; control (*n* = 10)*	Upper and lower body, high velocity	2	Strength, KE power, stair climbing power, chair stand, 6 m walk, 6 m backward walk, floor rise to stand, lift and reach	↑Strength + power, improved 6m walk, floor rise to stand, chair stand, lift and reach
de Vos et al. 2005	100 M+W, 69±6; control (*n* = 26)	Upper and lower body explosive training at 20%, 50%, and 80% 1RM	2–3	Strength, power, endurance	Similar increase in power for all groups, highest intensity group increased strength and endurance most

Note: M, men; W, women; LE, leg extension; EMG, electromyography; COPD, chronic obstructive pulmonary disease; CSA, cross-sectional area; RFP, rate of force production; GH, growth hormone; KE, knee extension; KF, knee flexion; DF, dorsiflexion; PF, plantar flexion; PT, peak torque; HE, hip extension; HF, hip flexion; ADL, activities of daily living; RM, repetition maximums. Asterisk indicates non-randomized.

2003; Miszko et al. 2003). Sayers et al. (2003) did not find any differences between the 2 groups for function or disability, although this pilot study was underpowered to address this statistically. On the other hand, Miszko et al. (2003) found that the power trainers improved function to a greater extent than strength trainers. This study used the innovative Continuous Scale Physical Functional Performance (CS-PFP) test, which assesses 16 everyday tasks with components for the lower body, the upper body, balance, and coordination, as well as endurance (Cress et al. 1996). Tasks were designed to simulate daily activities like dressing, doing the laundry, and carrying groceries. The power-training group was found to increase to a greater extent than the strength-training group for the total score, as well as for balance, endurance, and upper-body flexibility, even though the strength-training group did increase in strength more. Therefore, there is evidence that power training can improve functional performance and that the improvement can be greater than that achieved through strength training. More research is required to substantiate which form of training (strength vs. power) is more effective. Even within power training several different strategies have been used to increase power, ranging from low to high intensity. As previously mentioned, the ACSM position stand recommended that the intensity be about 40%–60% 1RM (Kraemer et al. 2002).

Recently, de Vos and colleagues (2005) examined the optimal load for increasing power at the same time as strength and endurance. All training subjects performed 3 sets of 8 repetitions twice each week for 8–12 weeks. The loads (20%, 50%, and 80% 1RM) were rapidly moved concentrically, then slowly moved during the eccentric phase. Loads of 20%, 50%, and 80% elicited similar increases in power, whereas 80% was most effective for enhancing strength and absolute endurance. From this research the authors suggest that high-load (80% 1RM) rapid repetitions be performed to achieve the largest benefits overall for power, strength, and endurance.

Safety of power training

One concern with older adults performing power training is the risk for injury. Many strength-training programs specifically instruct older adults to perform the movements in a slow and controlled fashion, presumably to reduce the risk of musculoskeletal injuries. This movement pattern is, however, contrary to the aims of power training, at least from the velocity of movement perspective.

The risks of strength training itself are not well defined, although the risk appears to be predominantly musculoskeletal and not cardiovascular (Latham et al. 2004). Although there have been hundreds of studies, most do not systematically monitor adverse events and many do not "make any comment about adverse events or side effects associated with" resistance training (Latham et al. 2004).

In the power-training studies in this review, several adverse events were reported. Of note, 1 study did report a case of disc herniation that may have resulted from the training program (Earles et al. 2001). Another reported an inguinal hernia that resulted from strength testing (de Vos et al. 2005). Other injuries included back pain (Earles et al. 2001), exacerbation of pre-existing osteoarthritis (Fielding et al. 2002; Henwood and Taaffe 2005; de Vos et al. 2005), minor strains (de Vos et al. 2005; Miszko et al. 2003), tendonitis (de Vos et al. 2005), plantar fasciitis (Fielding et al. 2002), and unspecified injuries leading to drop-out (Miszko et al. 2003). Other studies reported no adverse events (Bean et al. 2004) or did not make mention of adverse events.

A recent power-training study made the most systematic assessment of adverse events with the largest group of subjects (*n* = 112; de Vos et al. 2005). In this study, subjects were questioned weekly about health status and bodily pain. No cardiovascular events were reported, but there were 20 adverse events reported by 17 individuals. Sixteen of the adverse events occurred during testing (including the hernia) and all 4 of the adverse events that occurred during training occurred during the 80% 1RM condition. The reported adverse event rates relative to exposure were 0.34% (16 events, 4711 strength tests) for testing and 0.25% (4 events, 1633 training sessions) for training, suggesting a very low adverse event rate. Most of these injuries were resolved with changes to the training routine or anti-inflammatory and (or) analgesic medication, with the exception of the hernia, which had to be repaired surgically (de Vos et al. 2005).

To compare this recent research (de Vos et al. 2005) to other studies, injury rates can be calculated relative to the total number of individuals rather than exposure. The overall rate in this study (de Vos et al. 2005) is 15.1%, with 80% of the events occurring during testing. Pollock et al. (1991) found a similar overall injury rate for 1RM strength testing of 19.3% (11 of 57 subjects). Interestingly, although treadmill testing did not result in any injuries, the walk and (or) jog program in the same study (Pollock et al. 1991) had an injury rate of 42.9% (9 of 21 subjects). Most of the injuries occurred during the second phase of the 6-month training program when the training intensity increased to fast walking or jogging (Pollock et al. 1991). Therefore, although injuries do occur in power-training research studies using resistance training machines, it appears that the risk is likely substantially higher for a fast walk and (or) jog program. In fact, the risks associated with power-training research primarily occur during testing, so power-training programs with little or no testing likely have a low risk for injury. It should also be noted that since all the training injuries in the de Vos et al. (2005) study occurred during high-load (80% 1RM) training, lower-load training (50% 1RM) might be undertaken to reduce the risk of injury, even though the benefits to strength and endurance might be lower.

Power training and disability

The main purpose of including power training as part of an exercise program for older adults is to preserve or improve the ability of older adults to perform activities of daily living that require quick forceful motions. To date, the research provides evidence that laboratory performance tasks such as gait velocity, chair stands, and stair climbing can be improved with power training, and there is limited evidence that power training may be more effective than strength training. Only 2 studies on power training have gone beyond the laboratory to assess function in daily living. Kongsgaard et al. (2004) found improvements in self-reported activities of daily living (walking 400 m, stair climbing, and carrying

5 kg), as well as in self-reported health, in their male subjects with chronic obstructive pulmonary disease who underwent 12 weeks of power training. In the pilot study by Sayers et al. (2003) without a control group, improvements in some disability measures were found; however, there were no differences between the power- and strength-training groups.

Overall, as most of these studies were preliminary investigations of a new form of training for older adults several study design issues need to be addressed to provide any concrete evidence of the risks and benefits of power training. The following features should be included: randomization with control groups, sufficient sample size for disability outcome variables; blinding of assessors, concealment of allocation to groups, intention-to-treat analysis, and systematic monitoring of adverse events.

In addition to improving study design, researchers should examine the types of training that are undertaken to improve function and prevent disability. Performing a seated leg press powerfully in a horizontal movement, for example, may not translate well to getting out of a chair in a vertical direction. We found that a standing training program increased strength of the dorsiflexors in a standing position but had no effect in a supine position (Porter and Vandervoort 1997). For this reason, some authors have examined training program tasks that more closely emulate daily activities (Alexander et al. 2001; Bean et al. 2002; de Vreede et al. 2004). Examples included chair rises (Alexander et al. 2001), weighted stair climbing (Bean et al. 2002), and carrying objects (de Vreede et al. 2004). More research will need to be done to determine whether this type of training is more effective than resistance training in reducing or preventing disability.

Conclusions

Power training is receiving more attention as a means of improving the physical function of older adults because many functional tasks are more dependent on power than on strength. Power training has been successfully undertaken by healthy men and women, as well as by those with impaired physical function and residents of a long-term care facility. The evidence available indicates that power training is more effective than strength training in increasing power. There is also limited evidence that power training is more beneficial than strength training in enhancing physical function. Although injuries do occur in power-training studies, it appears that the risks are greatest for testing and for high-intensity (80% 1RM) training relative to lower-intensity (20% or 50% 1RM) training in healthy men and women. It appears that the risk and benefits will need to be weighed, as the overall benefits appear to be greatest for high-intensity (80% 1RM) training in terms of increasing power and strength in conjunction with endurance. Future well-designed randomized controlled trials should provide more evidence to guide practice in performing power training in older adults of varying health and functional status.

References

Alexander, N.B., Galecki, A.T., Grenier, M.L., Nyquist, L.V., Hofmeyer, M.R., Grunawalt, J.C., et al. 2001. Task-specific resistance training to improve the ability of activities of daily living-impaired older adults to rise from a bed and from a chair. J. Am. Geriatr. Soc. **49**: 1418–1427.

American College of Sports Medicine. 1998*a*. The recommended quantity and quality of exercise for developing and maintaining cardiorespiratory and muscular fitness, and flexibility in healthy adults. Med. Sci. Sports Exerc. **30**: 975–991.

American College of Sports Medicine. 1998*b*. Exercise and physical activity for older adults. Med. Sci. Sports Exerc. **30**: 992–1008.

Bassey, E.J., and Short, A.H. 1990. A new method for measuring power output in a single leg extension: feasibility, reliability, and validity. Eur. J. Appl. Physiol. **60**: 385–390.

Bassey, E.J., Fiatarone, M.A., O'Neill, E.F., Kelly, M., Evans, W.J., and Lipsitz, L.A. 1992. Leg extensor power and functional performance in very old men and women. Clin. Sci. **82**: 321–327.

Bean, J., Herman, S., Kiely, D.K., Callahan, D., Mizer, K., Frontera, W.R., and Fielding, R.A. 2002. Weighted stair climbing in mobility-limited older people: a pilot study. J. Am. Geriatr. Soc. **50**: 663–670.

Bean, J.F., Herman, S., Kiely, D.K., Frey, I.C., Leveille, S.G., Fielding, R.A., and Frontera, W.R. 2004. Increased velocity exercise specific to task (InVEST) training: a pilot study exploring effects on leg power, balance, and mobility in community-dwelling older women. J. Am. Geriatr. Soc. **52**: 799–804.

Cress, M.E., Buchner, D.M., Questad, K.A., Esselman, P.C., deLateur, B.J., and Schwartz, R.S. 1996. Continuous-scale physical functional performance in healthy older adults: a validation study. Arch. Phys. Med. Rehabil. **77**: 1243–1250.

Delorme, T.L. 1945. Restoration of muscle power by heavy-resistance exercises. J. Bone Joint Surg. **27**: 645–667.

de Vos, N.J., Singh, N.A., Ross, D.A., Stavrinos, T.M., Orr, R., and Fiatarone Singh, M.A. 2005. Optimal load for increasing muscle power during explosive resistance training in older adults. J. Gerontol. A Biol. Sci. Med. Sci. **60**: 638–647.

de Vreede, P.L., Samson, M.M., van Meeteren, N.L., van der Bom, J.G., Duursma, S.A., and Verhaar, H.J. 2004. Functional tasks exercise versus resistance exercise to improve daily function in older women: a feasibility study. Arch. Phys. Med. Rehabil. **85**: 1952–1961.

Earles, D.R., Judge, J.O., and Gunnarsson, O.T. 2001. Velocity training induces power-specific adaptations in highly functioning older adults. Arch. Phys. Med. Rehabil. **82**: 872–878.

Evans, W.J. 2000. Exercise strategies should be designed to increase muscle power. J. Gerontol. A Biol. Sci. Med. Sci. **55**: M309–M310.

Fiatarone, M.A., Marks, E.C., Ryan, N.D., Meredith, C.N., Lipitz, L.A., and Evans, W.J. 1990. High-intensity strength training in nonagenarians. J. Am. Med. Assoc. **263**: 3029–3034.

Fielding, R.A., LeBrasseur, N.K., Cuoco, A., Bean, J., Mizer, K., and Fiatarone Singh, M.A. 2002. High-velocity resistance training increases skeletal muscle peak power in older women. J. Am. Geriatr. Soc. **50**: 655–662.

Foldvari, M., Clark, M., Laviolette, L.C., Bernstein, M.A., Kaliton, D., Castaneda, C., et al. 2000. Association of muscle power with functional status in community-dwelling elderly women. J. Gerontol. A Biol. Sci. Med. Sci. **55**: M192–M199.

Frontera, W.R., Meredith, C.N., O'Reilly, K.P., Knuttgen, H.G., and Evans, W.J. 1988. Strength conditioning in older men: skeletal muscle hypertrophy and improved function. J. Appl. Physiol. **64**: 1038–1044.

Hakkinen, K., and Hakkinen, A. 1995. Neuromuscular adaptations during intensive strength training in middle-aged and elderly males and females. Electromyogr. Clin. Neurophysiol. **35**: 137–147.

Hakkinen, K., Kallinen, M., Izquierdo, M., Jokelainen, K., Lassila, H., Malkia, E., et al. 1998. Changes in agonist-antagonist EMG, muscle CSA, and force during strength training in middle-aged and older people. J. Appl. Physiol. **84**: 1341–1349.

Hakkinen, K., Kraemer, W.J., Newton, R.U., and Alen, M. 2001*a*. Changes in electromyographic activity, muscle fibre and force production characteristics during heavy resistance/power strength training in middle-aged and older men and women. Acta Physiol. Scand. **171**: 51–62.

Hakkinen, K., Pakarinen, A., Kraemer, W.J., Hakkinen, A., Valkeinen, H., and Alen, M. 2001*b*. Selective muscle hypertrophy, changes in EMG and force, and serum hormones during strength training in older women. J. Appl. Physiol. **91**: 569–580.

Health Canada. 1999. Canada's physical activity guide and handbook for older adults. Cat. No. H39-429/1999-2E. Health Canada, Ottawa, Ont.

Henwood, T.R., and Taaffe, D.R. 2005. Improved physical performance in older adults undertaking a short-term programme of high-velocity resistance training. Gerontology, **51**: 108–115.

Hruda, K.V., Hicks, A.L., and McCartney, N. 2003. Training for muscle power in older adults: Effects on functional abilities. Can. J. Appl. Physiol. **28**: 178–189.

Izquierdo, M., Hakkinen, K., Ibanez, J., Garrues, M., Anton, A., Zuniga, A., et al. 2001. Effects of strength training on muscle power and serum hormones in middle-aged and older men. J. Appl. Physiol. **90**: 1497–1507.

Jozsi, A.C., Campbell, W.W., Joseph, L., Davey, S.L., and Evans, W.J. 1999. Changes in power with resistance training in older and younger men and women. J. Gerontol. A Biol. Sci. Med. Sci. **54**: M591–M596.

Keysor, J.J. 2003. Does late-life physical activity or exercise prevent or minimize disablement? A critical review of the scientific evidence. Am. J. Prev. Med. **25**: 129–136.

Keysor, J.J., and Jette, A.M. 2001. Have we oversold the benefit of late-life exercise? J. Gerontol. A Biol. Sci. Med. Sci. **56A**: M412–M423.

Kongsgaard, M., Backer, V., Jorgensen, K., Kjaer, M., and Beyer, N. 2004. Heavy resistance training increases muscle size, strength and physical function in elderly male COPD-patients — a pilot study. Respir. Med. **98**: 1000–1007.

Kraemer, W.J., Adams, K., Cafarelli, E., Dudley, G.A., Dooly, C., Feigenbaum, M.S., et al. 2002. American College of Sports Medicine position stand. Progression models in resistance training for healthy adults. Med. Sci. Sports Exerc. **34**: 364–380.

Latham, N., Anderson, C., Bennett, D., and Stretton, C. 2003. Progressive resistance strength training for physical disability in older people. Cochrane Database Syst. Rev. CD002759.

Latham, N.K., Bennett, D.A., Stretton, C.M., and Anderson, C.S. 2004. Systematic review of progressive resistance strength training in older adults. J. Gerontol. A Biol. Sci. Med. Sci. **59**: 48–61.

Lexell, J., Taylor, C.C., and Sjostrom, M. 1988. What is the cause of the ageing atrophy? Total number, size and proportion of different fiber types studied in whole vastus lateralis muscle from 15- to 83-year-old men. J. Neurol. Sci. **84**: 275–294.

Metter, E.J., Conwit, R., Tobin, J., and Fozard, J.L. 1997. Age-associated loss of power and strength in the upper extremities in women and men. J. Gerontol. A Biol. Sci. Med. Sci. **52A**: B267–B276.

Metter, E.J., Talbot, L.A., Schrager, M., and Conwit, R.A. 2004. Arm-cranking muscle power and arm isometric muscle strength are independent predictors of all-cause mortality in men. J. Appl. Physiol. **96**: 814–821.

Miszko, T.A., Cress, M.E., Slade, J.M., Covey, C.J., Agrawal, S.K., and Doerr, C.E. 2003. Effect of strength and power training on physical function in community-dwelling older adults. J. Gerontol. A Biol. Sci. Med. Sci. **58**: 171–175.

Moritani, T., and DeVries, H.A. 1980. Potential for gross muscle hypertrophy in older men. J. Gerontol. **35**: 672–682.

Perkins, L.C., and Kaiser, H.L. 1961. Results of short term isotonic and isometric exercise programs in persons over sixty. Phys. Ther. Rev. **41**: 633–635.

Porter, M.M. 2001. The effects of strength training on sarcopenia. Can. J. Appl. Physiol. **26**: 123–141.

Porter, M.M., and Vandervoort, A.A. 1995. High intensity strength training for the older adult — a review. Top. Geriatr. Rehabil. **10**: 61–74.

Porter, M.M., and Vandervoort, A.A. 1997. Standing strength training of the ankle plantar and dorsiflexors in older women, using concentric and eccentric contractions. Eur. J. Appl. Physiol. **76**: 62–68.

Sayers, S.P., Bean, J., Cuoco, A., LeBrasseur, N.K., Jette, A., and Fielding, R.A. 2003. Changes in function and disability after resistance training: does velocity matter?: a pilot study. Am. J. Phys. Med. Rehabil. **82**: 605–613.

Signorile, J.F., Carmel, M.P., Czaja, S.J., Asfour, S.S., Morgan, R.O., Khalil, T.M., et al. 2002. Differential increases in average isokinetic power by specific muscle groups of older women due to variations in training and testing. J. Gerontol. A Biol. Sci. Med. Sci. **57**: M683–M690.

Skelton, D.A., Young, A., Greig, C.A., and Malbut, K.E. 1995. Effects of resistance training on strength, power, and selected functional abilities of women aged 75 and older. J. Am. Geriatr. Soc. **43**: 1081–1087.

Vandervoort, A.A., and McComas, A.J. 1986. Contractile changes in opposing muscles of the human ankle joint with aging. J. Appl. Physiol. **61**: 361–367.

Weir, J.P., and Cramer, J.T. 2006. Principles of musculoskeletal exercise programming. *In* ACSM's resource manual for guidelines for exercise testing and prescription. 5th ed. *Edited by* L.A. Kaminsky. Lippincott Williams & Wilkins, Philadelphia, Pa. p. 351.