Functional Benefit of Power Training for Older Adults

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Aging leads to significant losses in muscle mass, strength, and the ability to independently perform activities of daily living (ADL). Typically, standard resistance training (RT) has been used to reduce these losses in function by maintaining or even increasing muscle strength in older adults. Increasing strength does not necessarily, however, result in an increase in the ability to perform ADL. There is now research suggesting that muscle power is more closely associated with the performance of ADL than muscle strength is, so training for muscle power might lead to more beneficial results in functional performance. This review of studies investigating the effect of training on ADL performance in older adults indicated that standard RT is effective in increasing strength in older adults, but power training that contains high-velocity contractions might be a more optimal means of training older adults when the emphasis is on increasing the performance of ADL.

Key Words: strength, ADL, independence, successful aging, sarcopenia

One component of successful aging is the ability to independently perform activities of daily living (ADL) such as walking, climbing stairs, standing from a seated position, and simple lifting tasks. Age-related alterations in the cardiovascular, neuromuscular, and musculoskeletal systems, however, often make it difficult to complete these types of daily activities (Miszko et al., 2003). Training studies of older individuals traditionally use aerobic- and resistance-training (RT) exercises and report consequential increases in cardiorespiratory endurance and muscle strength, respectively. Recently, Latham, Bennett, Stretton, and Anderson (2004) completed a systematic review that suggested that although RT has a large positive effect on strength, it has only a small to moderate effect on functional ability, and increases in strength do not necessarily translate into improvements in ADL (Judge, Whipple, & Wolfson, 1994; Singh, Clements, & Fiatarone, 1997; Skelton, Young, Greig, & Malbut, 1995). A variety of studies indicate that muscle power is more strongly related than muscle strength to increases in performance of ADL (Bassey et al., 1992; Evans, 2000; Foldvari et al., 2000; Miszko et al., 2003), and decreases in muscle power have been closely associated with an inability to perform ADL (Bassey et al.; Earles, Judge, & Gunnarsson, 1997; Evans; Hunter, McCarthy,
& Bamman, 2004). Thus, when the outcome goal is an increase in ADL ability, training programs that focus on developing power might be more appropriate than standard RT programs that concentrate on increasing strength.

The classic force–velocity relationship demonstrates how force and velocity contribute to the product of skeletal-muscle power and illustrate that peak power is not developed at maximal force but rather at ~60–70% of maximal force and ~30–40% of maximal velocity (McComas, 1996). This implies that if the intent of training is to increase maximal power, a heavy load should be lifted, ideally at a velocity that is faster than typical movements. Bassey et al. conducted a study on leg-extensor-muscle power and performance in 13 men and 13 women in their ninth decade. They reported that leg-extensor power was significantly related to performance measures \( r = .65–.88 \) such as chair rising, stair climbing, and walking, suggesting that leg-extensor power might be a useful focal point for effective training. In 2000, Foldvari et al. published results from a 1-year clinical trial of community-dwelling older women (~75 years) in which the effects of a strength-, power-, and endurance-training program on performing basic ADL were evaluated. Results of their forward stepwise multiple-regression model indicated that leg-press power and habitual physical activity were the key predictors for effective functional status in older women \( r = .64 \). Similar outcomes were reported by Bean, Kiely, et al. (2002) for community-dwelling mobility-limited individuals age 65–83 years. Leg-muscle power and leg strength were strongly related to each other \( r = .89 \), but the authors suggested that leg power had a greater influence on function \( r^2 \approx .43 \) than did muscle strength \( r^2 \approx .39 \). Overall, results from these and other studies (Figure 1) suggest that when the goal is to enhance ADL, a training program that focuses on developing muscle power is likely effective. Because training studies have evaluated ADL through both subjective (questionnaire based) and objective (performance test) measures, extrapolation of results across studies must be made with caution.

**Power Training and Older Adults**

Skeletal-muscle power is the product of force (load, muscle strength) and the velocity of the muscle contraction; in other words, if strength is the ability to produce force, power is the ability to produce force quickly (Bean, Herman, et al., 2002; Bean, Kiely, et al., 2002). For older adults, power training consists of performing a traditional RT exercise with the concentric portion (lifting or pushing) being completed as fast as possible and the eccentric (lowering) portion completed in approximately 2–3 s (Fielding et al., 2002; Henwood & Taaffe, 2005; Miszko et al., 2003). The most appropriate velocity for the concentric portion and the load employed, however, has yet to be established. For example, de Vos et al. (2005) suggest that lifting heavier loads as fast as possible is the most efficient method to improve power, as well as strength and endurance, in older adults, whereas Orr et al. (2006) reported that lifting light loads as fast as possible resulted in the greatest improvements in function (balance). Signorile, Carmel, Lai, and Roos (2005) also reported that power is more effectively trained using lower loads at higher velocities, whereas strength is increased with higher loads and lower velocities. Specific recommendations for program design are premature because more research is warranted that uses a variety of loads and velocities to determine the most appropriate
With high-velocity training in which fast movements are performed with varying loads, safety becomes an initial concern for the older adult population, and guidelines need to be developed. Although there have been some adverse effects of high-velocity training, the majority occurring during the testing portion of the study, any incidents encountered during the training portion are often resolved with small changes to the training protocol or anti-inflammatory medication (reviewed in Porter, 2006). One study on patients with chronic obstructive pulmonary disease (Kongsgaard, Backer, Jørgensen, Kjaer, & Beyer, 2004) demonstrated that high-velocity training resulted in beneficial adaptations in physical function, and in this high-risk group the results presented made no indication of compromised safety or injury associated with the training. Only longitudinal reporting of the adverse events associated with high-velocity training will resolve these issues. Moreover, future research should consider reporting safety and injury incidents, and inevitably the growth of this area of training literature will enable solid recommendations to be made with respect to power-lifting protocols and safety.

In addition to the importance of velocity and load, specificity of training should not be overlooked because it might play a significant role in enhancing ADL in older adults. Most studies do not take into account the rate at which different skeletal muscles weaken and contractile properties slow with the aging process. For example,
in the quadriceps femoris there is a substantial decline in maximal force-generating capacity, whereas the tibialis anterior weakens considerably less with age but its contractile properties slow significantly \((\text{Jakobi, Connelly, Roos, Allman, & Rice, 1999})\), yet all muscles are typically trained in a similar manner with the focus on regaining maximal force. Based on these differential age-related alterations between skeletal muscles and the inconsistent changes in ADL after RT, training programs need to be designed with some consideration of the changes unique to each muscle. Power-training programs develop both strength and the speed of contraction and thus by default target the differential age-related changes most likely contributing to decreased skeletal-muscle function and a decline in ADL ability.

In addition to training specificity, there should also be more concern about the functional tests used to assess ADL. RT programs using numerous populations, protocols, and durations \((\text{Judge et al., 1994; Singh et al., 1997; Skelton et al., 1995})\) have shown consistent increases in strength but equivocal findings concerning improvements in a variety of functional-performance tests (questionnaires, gait velocity, chair-rise time, 6-min walk, knee-rise time, bag raise (kg), and floor-rise time). In contrast to this and in light of the paucity of literature on high-velocity training and ADL performance \((\text{Table 1})\), power studies typically report an increase in ADL irrespective of the functional test used. This suggests that when training older adults to improve functional performance, in particular with RT and high-velocity training, using a battery of subjective and objective functional-assessment tools to determine the effectiveness of an intervention would be more beneficial.

### Muscle Power and Function

The concept that muscle power might be more closely related to muscle function than strength is \((\text{Runge, Rhyfeld, & Resnicek, 2000; Runge, Rittweger, Russo, Schiessl, & Felsenberg, 2004})\) has initiated a change in the design of training programs for older adults. Generally, muscle power declines with age, and this failure to produce force rapidly is likely the result of age-related atrophy in fast-twitch fibers \((\text{Häkkinen et al., 1996; Izquierdo et al., 1999})\). Klein, Allman, Marsh, and Rice \((2002)\) reported that as we age there is a decline in Type II fiber size and speculated that this alteration is likely caused by less recruitment of Type II fibers resulting from a decrease in number and/or intensity of contractions. Kostka \((2005)\) also reported a decrease in muscle-fiber-shortening velocity with increasing age that resulted in decreased power. Muscle power might be enhanced with exercises typically used during RT, but at higher velocities \((\text{as fast as possible, <1 s})\). Collectively, high-velocity training might promote greater increases in motor-unit activation than RT does, which result in greater adaptations in Type II fibers and thus improvements in the rate of force development \((\text{Häkkinen et al., 1998})\). This improvement might ultimately be more important in the ability to perform ADL than peak force generation is \((\text{Evans, 2000})\).

Although the most appropriate training program has yet to be determined, there has been growing research interest in the effectiveness of power training to enhance ADL. The investigations included in Table 1 are clear illustrations of high-velocity power training in older adults with respect to ADL. All studies used a control group that engaged in activities such as low-velocity training, walking, or no exercise. Some studies were excluded from this review if the criteria of high
Table 1  High-Velocity-Training Studies

<table>
<thead>
<tr>
<th>Study</th>
<th>Age (years)</th>
<th>n by sex</th>
<th>Exercise area</th>
<th>Weeks</th>
<th>Times/week</th>
<th>Sets, reps</th>
<th>% 1RM</th>
<th>PWR</th>
<th>ST</th>
<th>ADL</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bean et al., 2004</td>
<td>70+ Ind</td>
<td>10 M</td>
<td>UPR, LWR</td>
<td>12</td>
<td>3</td>
<td>3, 10</td>
<td>2+ (% of BW)$</td>
<td>↑12–30%*</td>
<td>NT</td>
<td>↑*</td>
</tr>
<tr>
<td>Earles et al., 2001</td>
<td>70+ Ind</td>
<td>7 M, 11 W</td>
<td>LWR</td>
<td>12</td>
<td>3</td>
<td>3, 10</td>
<td>4–12 (% of BW)</td>
<td>↑22–150%*</td>
<td>↑22%</td>
<td>↔</td>
</tr>
<tr>
<td>Henwood &amp; Taaffe, 2005</td>
<td>60–80 Ind</td>
<td>5 M, 10 W</td>
<td>UPR, LWR</td>
<td>8</td>
<td>2</td>
<td>3, 8</td>
<td>33, 55, 75</td>
<td>↑17–30%*</td>
<td>↑21–82%*</td>
<td>↑*</td>
</tr>
<tr>
<td>Hruda et al., 2003</td>
<td>76–90 Dep</td>
<td>5 M, 13 W</td>
<td>LWR</td>
<td>10</td>
<td>3</td>
<td>1+, 4–8+</td>
<td>NA^</td>
<td>↑44–60%*</td>
<td>↑25–30%*</td>
<td>↑*</td>
</tr>
<tr>
<td>Kongsgaard et al., 2004</td>
<td>65–80 Dep COPD</td>
<td>6 M</td>
<td>LWR</td>
<td>12</td>
<td>2</td>
<td>4, 8</td>
<td>80</td>
<td>↑19%*</td>
<td>↑14–18%*</td>
<td>↑*</td>
</tr>
<tr>
<td>Miszko et al., 2003</td>
<td>65–90 Ind</td>
<td>5 M, 6 W</td>
<td>UPR, LWR</td>
<td>16</td>
<td>3</td>
<td>3, 6–8</td>
<td>40</td>
<td>↑8% (&amp;)</td>
<td>↑12–13%*</td>
<td>↑*</td>
</tr>
<tr>
<td>Orr et al., 2006</td>
<td>60+ Ind</td>
<td>11 M, 17 W</td>
<td>UPR, LWR</td>
<td>12</td>
<td>2</td>
<td>3, 8</td>
<td>20, 50, 80</td>
<td>↑14–15%*</td>
<td>↑13–20%*</td>
<td>↑*</td>
</tr>
<tr>
<td>Fielding et al., 2002#</td>
<td>65+ Ind</td>
<td>15 W</td>
<td>LWR</td>
<td>16</td>
<td>3</td>
<td>3, 8</td>
<td>70</td>
<td>↑35–97%*</td>
<td>↑35–45%*</td>
<td>NT</td>
</tr>
<tr>
<td>Sayers et al., 2003#</td>
<td>65+ Ind</td>
<td>15 W</td>
<td>LWR</td>
<td>16</td>
<td>3</td>
<td>3, 8</td>
<td>70</td>
<td>NT</td>
<td>NT</td>
<td>↑*</td>
</tr>
</tbody>
</table>

Note. 1RM = one-repetition maximum; PWR = power; ST = strength; ADL = activities of daily living; Ind = independent (community-dwelling); Dep = dependent (assisted living); M = men; W = women; LWR = lower body; UPR = upper body; + = or more; BW = body weight; NA = not available; ^ = used Therabands; $ = used weighted vests; & = Wingate; NT = not tested; # = linked studies (same experiment but strength/power reported in Fielding et al., 2002, and ADL reported in Sayers et al., 2003); COPD = chronic obstructive pulmonary disease; ↑ = increase; ↔ = no change. Training velocity in all studies was as fast as possible. In the study by Orr et al. (2006) all three experimental groups had the same number of men and women in each group as illustrated in the table.

*p < .05.
velocity and its relationship or effect on ADL in older adults were not met (de Vos et al., 2005; Signorile et al., 2002). Recently, Fatouros et al. (2005) reported using high-velocity training in inactive older men, but this study was not what we consider high velocity because the contraction duration was 6–9 s (2–3 s to raise the weight, 2- to 3-s pause, 2–3 s to lower the weight). Rather than a specific time, some researchers (Bean et al. 2004; Fielding et al., 2002; Hruda, Hicks, & McCartney 2003) have instructed participants to lift as fast as possible. The important aspect of high-velocity training might be moving as fast as possible, which might differ between individuals depending on their age and ability, rather than in a given period of time. Several RT studies that employed “explosive” high-velocity components were not included in this review because they did not examine the effect of training on improving ADL (Häkkinen, Alen, Kallinen, Newton, & Kraemer, 2000; Häkkinen et al., 1998; Izquierdo et al., 2001). The studies included in this article (Table 1) used a fast concentric phase of work and examined the influence of this type of training on enhancing ADL in older adults.

Changes in Functional Performance

The work of Earles, Judge, and Gunnarsson (2001) represents an early attempt to clearly determine the effectiveness of power training on improving functional performance in older men and women (mean age 78 years). They conducted a 12-week velocity-based training program three times per week using three sets of 10 repetitions with progressively increasing loads at varied velocities. For the first 2 weeks the first set of each exercise was performed at a comfortable but not slow speed, the second set with a ramped protocol (first three repetitions at comfortable but not slow speed, next three repetitions performed a little bit faster, and the last four repetitions performed as fast as possible), and the third set at high velocity (as fast as possible). The remaining 10 weeks of the training program had participants use the ramp-velocity protocol for the first set to prevent injury, and the subsequent two sets were performed with high-velocity contractions. The exercises included leg press, hip flexion, step-ups, chair rises, and plantar flexion, which all resulted in increases in strength (22%) and power (22%) assessed by velocity and power measurements on a pneumatic leg-press machine. Improvements in functional performance were assessed using the 6-min walk and the Short Physical Performance Battery, a lower extremity performance test evaluating three components that assess balance (on one foot and two), chair rise, and 8-ft walk. No improvements were reported with this training, but this might be attributable to the initial high-functioning status of the participants (Earles et al., 2001) or the fact that not all exercise sets were performed at a high velocity, as has been suggested by Henwood and Taaffe (2005).

Employing an 8-week, twice-weekly, high-velocity RT protocol for 15 healthy (age 60–80 years) community-dwelling older adults, Henwood and Taaffe (2005) observed an increase in ADL. Three sets of six to eight repetitions at 65–70% one-repetition maximum (1-RM) were performed during the first 2 weeks of training. Subsequently, training consisted of three sets of eight repetitions with 35%, 55%, and 75% of 1-RM, with the concentric portion being completed as fast as possible. This high-velocity-training study demonstrated that dynamic muscle strength increased approximately 21–82% and muscle power increased approximately
17–30%. More important, functional-performance scores improved 7–26% (6-m walk, floor rise to standing, repeated chair rise, lift and reach) with high-velocity training.

Miszko et al. (2003) used an 8-week RT protocol to develop a base strength level and subsequently used high-velocity training. During the initial 8 weeks of the study, 65- to 90-year-old men and women performed three sets of six to eight repetitions of three upper and three lower body exercises three times per week at an intensity of 50–70% 1-RM. For the next 8 weeks, the RT group began lifting at 80% 1-RM, and the power-training group began lifting at 40% 1-RM with the concentric portion being completed as fast as possible (high velocity). The results demonstrated that both programs were similarly effective in increasing strength, but, more important, the power-trained group performed significantly better (pretraining power 58.2 ± 13, posttraining power 67.1 ± 13, pretraining strength 55.5 ± 10, posttraining strength 57.5 ± 10) in the functional tasks as measured by the Continuous Scale Physical Functional Performance test. To date, this seems to be the clearest comparison in one experimental report of high-velocity power training with traditional strength training and physical function.

Fielding et al. (2002) and Sayers et al. (2003) compared strength training with high-velocity training in 30 women age 65 and older. The RT protocol consisted of three sets of eight repetitions at 70% 1-RM completed three times per week for 16 weeks for both leg-press and knee-extension exercises on a pneumatic-resistance machine. The key difference between the strength-training group and the power-training group was that the concentric portion of the exercise was executed as fast as possible (<1 s) by the power-training group. Fielding et al. reported that both training groups increased strength similarly, but the high-velocity-trained group also significantly increased leg-press (35%) and knee-extensor power (97%). Sayers et al. reported that as a result of this training both groups improved similarly on a battery of functional tasks (dynamic balance, stair-climb time, chair-rise time, and gait velocity). The lack of greater functional gains after high-velocity training led the authors to suggest that although high-velocity training was beneficial to older adults, the exercises should more closely resemble ADL.

**Innovative Training Programs**

Novel approaches to high-velocity training with a focus on improving muscle power and enhancing function while taking advantage of training specificity have been undertaken. A lack of accessibility to private gyms and expensive machines led Hruda, Hicks, and McCartney (2003) to use resistance bands as a more practical and accessible means to improve power and functional ability in older men and women (~85 years) living in a long-term residential home. They theorized that training with resistant bands (Therabands) improved strength and power versus the traditional RT programs and would provide older individuals who had limited community mobility a home-based and cost-effective way to enhance ADL. Individuals trained the main muscles of the lower body using seated and standing exercises, with a gradual introduction of the Therabands as an individual’s own body weight as resistance became too easy. The seated exercises included leg crosses, hip rotations, ankle rotations, and rising from a seated position. The standing exercises included heel raises, squats, leg lifts, and hamstring curls for one set of four to
eight repetitions at first, and the number of both sets and repetitions was increased when possible. The key to the training was that all participants were instructed to complete the concentric portion of each movement as fast as possible. These trained participants, compared with the nonexercised control group, showed significant increases in peak torque (27.3%) and average power (50.6%) as assessed by a Biodex exercise dynamometer. More important, the trained participants showed significant improvements in the 8-ft up-and-go timed test (–32.4%), a 30-s chair stand (66.2%), and a 6-m walk (–36.1%). These improvements could be functionally relevant in building older adults’ ability to successfully cross roadway intersections in the allotted walk-light time.

Rather than standard fitness equipment or resistance bands, Bean et al. (2004) used fitted weighted vests for power training. Initially, vest weights were 2% of each participant’s body weight and were either increased or decreased depending on the participant’s performance in order to improve power and ADL. The protocol, InVEST (Increased Velocity Exercise Specific to Task), included exercises that were ADL specific, such as chair stands, toe raises, pelvic raises, step-ups, seated triceps dips, and chest press, which were performed three times per week for 12 weeks. These activities were chosen to represent normal daily functional tasks to optimize the principal of training specificity. The concentric (rising) portion of each exercise was also performed as fast as possible. The participants were older women (70+ years), and functional-test performance was measured using the Short Physical Performance Battery, as well as standing balance (one leg), timed walk, and a timed test of five repetitions of rising from a chair and sitting down. This InVEST training protocol resulted in muscle power increasing 12–36% as assessed by a pneumatic-resistance machine and improvements in functional performance such as a reduced chair-stand time, increased gait speed, increased balance, and significant increases in Short Physical Performance Battery performance. These results provide evidence that this weighted-vest protocol, which draws on the principle of training specificity, is very effective in increasing not only muscle strength and power but also, and more important, functional performance. These vests are a low-cost method of training, and all the exercises included in the training protocol can be done at home with appropriate safety precautions.

Conclusion

For many years one of the main focuses of training older individuals has been on developing muscle strength to combat sarcopenia and enhance function. These standard RT protocols have demonstrated that they can be used to increase muscle strength, but with equivocal effects on muscle power and on the ability to perform ADL, in older adults (Latham et al., 2004). With the recent indication that muscle power is more closely related to the ability to perform ADL than strength, research initiatives are beginning to focus on increasing muscle power in order to improve function. To date, training programs that intend to increase muscle power through high-velocity movements have yet to determine the most appropriate training protocol, yet the limited research with varying training programs suggests that when the concentric portion of a contraction is executed as fast as possible, muscle power increases and this enhances ADL-outcomes measures. These early studies, only one of which made a direct comparison between resistance and high-velocity
training (Miszko et al., 2003), indicate that power training might be a useful tool for rehabilitation and prevention of age-related declines in function. There is no dispute that a progressive RT protocol will increase an older individual’s strength; however, a training program that focuses on concentric high-velocity contractions might be a more optimal regimen to elicit positive and consistent results with respect to ADL and certainly warrants continued and greater research efforts.

References


