

Resistance Training for Better Health in Older Adults

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[Received July 19, 2005 ; Accepted November 16, 2005]

There is increasing research evidence for the efficacy of resistance training programs for improving health and functional status in older adults. Resistance training has been shown to be an effective method to avoid age related losses in skeletal muscle tissue. Resistance training appears to be a potential solution for prevention purposes by inducing increases in strength, power and muscle cross sectional area, in addition to moderately improving endurance. There are also improvements in some aspects of functional status such as walking speed. Further research is required to determine the efficacy of resistance exercise for fall prevention. It does appear that muscular power and rate of force development are important indicators of health and functional status in older adults. Therefore resistance training programs should incorporate some of these aspects into the program design. Resistance training also provides an alternative method of rehabilitation for various disease states such as cardiovascular disease and type II diabetes. It now appears that resistance training is a critical component of exercise programs designed to improve health in older populations and should receive similar emphasis to aerobic activities such as walking.

Keywords: weight training, aging, power

[International Journal of Sport and Health Science Vol.4, 19-28, 2006]

1. Introduction

The reduction in muscular strength with aging results in physical disability and frailty and a loss of independent function and contributes to escalating health care costs. Research suggests that maintenance of strength throughout the lifespan may reduce the prevalence of functional limitations (Brill, et al., 2000). A recent review outlined strategies for family physicians to increase exercise levels in frail elders (Heath, et al., 2002). It was suggested that exercise can be considered for both enhancing lifestyle and as a targeted disease state intervention. Resistance training has been shown to have a myriad of health benefits for older populations. In this article we present research on the benefits of resistance exercise for older adults. There is now a growing body of scientific literature that clearly indicates the benefits of this mode of exercise for a wide range of clinical populations, in addition to healthy older adults. However, a recent report indicates that the vast majority of adults in the United States over the age of 65 do not engage in any form of resistance

exercise (CDC, 2001; Galuska, et al., 2002). This is despite a national health objective for 2010 in the US being to increase to 30% the proportion of adults who perform, for at least 2 days per week, activities that enhance and maintain muscular strength and endurance (Galuska, et al., 2002).

2. Age related loss of strength

There is an age related loss of muscular strength and power, predominantly as a result of loss of muscle mass. With increasing age and the low activity levels seen in the elderly, muscle strength is a critical component of walking ability (Evans, 1996). Reduced lower extremity strength has been associated with reduction in gait speed (Bendall, et al., 1989; Chandler, et al., 1998), balance, stair-climbing ability (Fiatarone, et al., 1990) and getting up from a seated position (Bassey, et al., 1992; Chandler, et al., 1998). Bassey and colleagues (1992) found that leg extensor power was significantly correlated with all performance measures, especially in women. Clearly there is a

need to maintain muscle power in old age and this appears to be especially important in women. In a study by Chandler, et al., (1998) lower extremity strength gains were associated with gains in chair rise performance, gait speed, and in mobility tasks such as gait, transfers, stooping, and stair climbing. Strength gain was also associated with improvement in confidence in mobility. Exercise participants received strengthening exercises in their homes three times a week for ten weeks while control subjects continued their normal activities.

3. Sarcopenia

Sarcopenia refers to the progressive loss of skeletal muscle tissue and the subsequent muscle weakness associated with ageing and reduced levels of physical activity. Resistance training to produce muscle hypertrophy appears to be instrumental in limiting sarcopenia (Fiatarone, et al., 1990). Resistance training results in significant increases in both whole muscle and fiber cross sectional area in older populations (Campbell, et al., 2002; Fiatarone, et al., 1990; Fiatarone, et al., 1994; Frontera, et al., 2003; Frontera, et al., 1988; Häkkinen, et al., 2002; Häkkinen, et al., 2001; Hikida, et al., 2000). One of the early studies by Frontera and colleagues (1988) showed that older men have the capacity to make large increases in muscular strength and muscle cross-sectional area following 12 weeks of resistance training. Fiatarone, et al., (1990) demonstrated that women older than 90 yrs could significantly increase muscular strength, muscle cross sectional area and functional status following a resistance training program.

A randomized, controlled trial by Fiatarone, et al., (1994) in 100 nursing home residents (mean age 87 years) increased thigh cross sectional area, in addition to significantly improving strength, walking velocity, stair climbing power and spontaneous activity levels. Following a 24 week heavy resistance/power training program in 21 older adults, there were significant increases in fiber type cross sectional area for all three subtypes (I, IIA and IIB) (Häkkinen, et al., 2002). This was in addition to increases in lower body strength and chair rise time. Increases in muscle fiber cross sectional area and whole muscle size has been consistently shown to occur following high intensity resistance training programs of sufficient duration (Häkkinen, et al., 2001). Sixteen

weeks of high intensity resistance training was shown to significantly increase muscle fiber cross-sectional area in older previously untrained men (Hikida, et al., 2000).

4. Falls and Balance

In the elderly, walking speed has been related positively to gastrocnemius strength (Bassey, et al., 1992; Bendall, et al., 1989). It has been suggested that improvements in lower extremity strength and encouragement of regular exercise might prevent significant loss of walking speed (Bassey, et al., 1992). In addition, lower extremity weakness has been demonstrated to be a significant risk factor for falls (Moreland, et al., 2004). Despite this finding there is limited research that demonstrates that exercise is effective for preventing falls (Liu-Ambrose, et al., 2004; Wolfson, et al., 1995). A recent study by Liu-Ambrose and colleagues (2004) showed that high intensity resistance training significantly reduced fall risk scores by 57% in older women with low bone mass. Lamoureux, et al., (2002) showed that muscular strength is a critical requirement for negotiating obstacles in older men and women and that a progressive resistance training program can significantly improve obstructed gait function (Lamoureux, et al., 2003). They also showed that as the difficulty of tasks increased, the magnitude of the relationship between muscular strength and destabilizing activities increased (Lamoureux, et al., 2002).

Resistance training has also been demonstrated to improve stair climbing ability (Vincent, et al., 2002b). However, not all studies have shown positive improvements in fall risk in older populations (Latham, et al., 2003). This study used a commonly used model of training, which involved three sets of eight repetitions of leg extensions (Latham, et al., 2003) which is not a function specific movement. Therefore it is not surprising that significant improvements in physical function were not seen. Further research is required to clearly demonstrate that resistance exercise is an important preventative strategy for falls in older populations. There does appear to be some support for increasing lower body strength in particular to help older adults remain functionally mobile and reducing their vulnerability to falls.

5. Resistance Training for Older Populations

It is apparent that an increase in strength in deconditioned older adults is associated with improvements in physical function (Brown, et al., 1990; Brown, et al., 1995; Buchner, et al., 1997; Fiatarone, et al., 1990; Frontera, et al., 1990; Sipila, et al., 1995; Sipila, et al., et al., 1996). Elderly subjects have responded to weight training in a qualitatively similar manner as younger subjects. Studies have demonstrated large increases in maximum loads lifted and accompanying enlargement of whole muscle and muscle fiber areas (Brown, et al., 1990; Charlette, et al., 1991; Häkkinen, et al., 1998; Sipila, et al., 1997). The trainability of skeletal muscle appears to be unaffected by age and strength loss appears to be reversible even in the oldest members of the population (Fiatarone, et al., 1990). Strength gains of 32 - 227% are reported in the literature from resistance training for eight or more weeks (Brandon, et al., 2000; Fiatarone, et al., 1990; Judge, et al., 1993; Pyka, et al., 1994). Differences in the length of the programs and the initial strength values of participants from the various studies might partly explain why different rates of strength gains are reported in the literature.

Muscular power appears to be even more important than muscular strength for older populations (Evans, et al., 2000). There are several studies showing a clear relationship between muscular power and functional status (Bassey, et al., 1992; Bean, et al., 2002b; Foldvari, et al., 2000; Suzuki, et al., 2001). Suzuki, et al. (2001) demonstrated that there was a positive correlation between the muscle power of the plantar flexors and dorsi flexors and measures of functional status (chair rise time, stair climb time, gait velocity). Foldvari, et al. (2000) showed that leg power was a significant predictor of self reported functional status in sedentary older women. Both leg power and habitual physical activity were related to self reported functional status in this subject group. It has also been shown that muscular power deteriorates at a faster rate than muscular strength (Bassey, et al., 1992). Several training studies using power training have been conducted and the results show that older individuals can significantly improve muscle power and strength (Bean, et al., 2004; Bean, et al., 2002a; Earles, et al., 2001; Häkkinen, et al., 2002; Izquierdo, et al., 2001; Newton, et al., 2002). Increases in power

have also been related to improvements in balance and mobility (Bean, et al., 2004). Izquierdo, et al., (2001) trained both older and middle aged men using both traditional and power movements for 16 weeks. There were significant improvements in maximal strength and power. Power development programs for the elderly may help optimize functional abilities as well as have secondary effects on other physiological systems (e.g., connective tissue) (Bassey, et al., 1992). Not all studies have been successful in improving functional status following high velocity resistance training programs (Earles, et al., 2001). This is despite the large increases in both strength and power with this mode of training. The challenge for researchers now is determine the optimum training program that can be used in these populations to improve both power and functional ability.

Another measure that is similar to muscular power is the ability to develop force rapidly or rate of force development (RFD). RFD provides a measure of the ability to develop a rapid rise in muscle force ($\Delta\text{Force}/\Delta\text{time}$). It would appear that this is an important characteristic for activities such as walking, climbing stairs and avoiding falls (Bassey, et al., 1992). Maximal walking speed has been shown to be significantly correlated to rate of force development in older adults following resistance training ($r = 0.86$) (Suetta, et al., 2004). Resistance training has been shown to significantly increase RFD both in healthy elderly (Häkkinen, et al., 2001) and also in elderly men and women recovering from hip surgery and long term muscle disuse (Suetta, et al., 2004).

It has been observed that short-term resistance training exercises increase the synthetic rate of the major contractile proteins myosin, actin and mixed muscle proteins in seven elderly subjects (Hasten, et al., 2000). The acute exercise induced increase in contractile protein synthesis rate is similar in young, middle-aged and elderly men and women (Hasten, et al., 2000). This suggests that the protein synthetic machinery adapts rapidly to increased contractile activity and that the adaptive responses are maintained throughout adulthood and into old age. It has been found that three months of resistance training increased the synthetic rates of mixed muscle proteins in physically frail women ($n = 8$) and men ($n = 4$) older than 76 years (Yarasheski, et al., 1999). Most models of resistance training in the elderly use single joint or open kinetic chain exercises as the

basis of the training programs. Closed kinetic chain exercises such as squats and power cleans have been suggested to be more functional models of lifting and may provide greater benefits for measures of functional capacity in addition to improving strength (Panariello, et al., 1991). Sharman, et al., (2000) used squats, power cleans and deadlifts as the basis of a 24-week training program in 20 healthy elderly subjects. There were no reports of musculoskeletal injury or excessive muscular soreness as a result of this mode of training so it appears that older people can tolerate such intensities of training using complex multi-joint movements and produce considerable improvements in quality and quantity of muscle.

6. Cardiovascular Adaptations with Resistance Training

Aging and inactivity have been found to result in a reduction of the capillary supply to skeletal muscle (Coggan, et al., 1992). Whereas capillary density was increased significantly only after aerobic training, both resistance and aerobic training increased the size of the capillary-to-fibre interface, suggesting an increased structural capacity for oxygen flux after both forms of training (Hepple, et al., 2000). In addition to improving muscular strength and power, resistance exercise has been demonstrated to improve cardiorespiratory endurance in elderly men and women (Izquierdo, et al., 2003; Vincent, et al., 2002a). In a study of 62 older men and women, time to exhaustion on a treadmill was increased by 26.4% and 23.3% in low intensity and high intensity resistance trained groups respectively. This data suggests that resistance exercise may be a viable method for improving cardiorespiratory endurance in older populations. It was also clear that resistance training alone provided a reasonably effective training stimulus for improving $VO_{2\text{ peak}}$ in agreement with previous findings for this population (Frontera, et al., 1990). Izquierdo, et al., (2003) showed that resistance training results in a significant improvement in maximal and submaximal endurance after 16 weeks of training.

In addition to improving strength, resistance training has been shown to improve gait measures. Judge, et al., (1993) found that 12 weeks of resistance and balance training in 31 older adults (mean age = 82.1 years) significantly improved usual gait velocity by 8% ($p < 0.05$). Resistance training has

also been shown to improve walking endurance in older individuals. Ades, et al., (1996) studied the effect of a resistance training programme on walking endurance in a healthy, community-dwelling elderly population. Participants in the resistance-training programme increased submaximal walking endurance by 38%, whereas no change was seen in controls. The relation between change in leg strength and change in walking endurance was significant ($r = 0.48$). This finding is relevant to older persons at risk for disability, because walking endurance and leg strength are important components of functional status.

7. Resistance Training and Disease

7.1. Cardiovascular Disease

Resistance training offers a viable method of improving functional status in individuals who have decreased levels of functioning as a result of chronic disease states. The American Heart Association has a position stand that outlines the role of resistance exercise for patients with cardiovascular disease (Pollock, et al., 2000). They suggest that moderate resistance exercise provides a safe and effective method for improving strength and endurance, in addition to helping to prevent and manage a number of chronic conditions and improve cardiovascular risk factors (Pollock, et al., 2000). Resistance training, when combined with aerobic exercise has been shown to improve vascular function in a variety of older populations (Ades, et al., 2003; Green, et al., 2004; McGavock, et al., 2004). Resistance training has been shown to improve exercise performance and skeletal muscle function in patients with chronic heart failure (Pu, et al., 2001). A randomized, controlled trial demonstrated that high intensity resistance training significantly improved muscular strength, muscular endurance, 6-minute walk distance, in addition to improving skeletal muscle characteristics (Pu, et al., 2001). A recent study showed that six months of resistance training improved a wide range of measured physical activities (stair climbing, bed making, and carrying objects) in older women with coronary heart disease. Maximal power for activities that involved weight-bearing also increased significantly following the resistance training program.

7.2. Peripheral Arterial Disease (PAD)

It is evident from previous training studies that there is a wide range of improvements observed in walking ability and blood flow in patients with PAD. Differences in the components of the exercise programs, such as intensity, duration and frequency of exercise sessions, may account for the large variation in improvements. Also the severity and extent of the disease, along with differing degrees of accompanying risk factors could be responsible for the varied responses to exercise. Most studies have used walking exercise as the basis of the exercise rehabilitation. There is mounting evidence that leg strength is strongly associated with disease severity and lower-extremity exercise capacity (McDermott, et al., 2004a; McDermott, et al., 2004b). It also appears that muscular power may be an important factor in the limited functional performance in patients with PAD (McDermott, et al., 2004b). We recently conducted randomized, controlled study that showed that progressive resistance training significantly increased muscular strength, in addition to increasing muscle fiber size and capillarity in the gastrocnemius (McGuigan, et al., 2001). This was in addition to significant improvements in maximal walking capacity.

7.3. Alzheimer's Disease (AD)

Regular physical activity throughout life and by older people has been demonstrated to lower the risk of developing cognitive impairment, AD, and dementia of any type (Laurin, et al., 2001; Pope, et al., 2003). Interestingly, the same risk factors for cardiovascular disease apply to AD and therefore appropriate physical activity combined with nutrition intervention can reduce risk of developing this disease. Total cholesterol, LDL/HDL ratio, total triglycerides, and homocysteine are risk factors that can have been shown to decrease in the blood with chronic resistance training. In addition, hypertension, excessive body fat, insulin resistance and type II diabetes are also risk factors for AD that respond well to resistance training (Pope, et al., 2003).

However, once a person is diagnosed with AD there remains strong efficacy for resistance training to reduce the muscle and bone loss, maintain function, improve behaviour (e.g. reduce aggression), and slow cognitive and memory decline. For example,

people suffering from dementia often present with declining neuromuscular function and importantly resistance exercise is effective for slowing and even reversing this decline (Teri, et al., 1998; Thomas & Hageman, et al., 2003). Unexplained weight loss and cachexia are frequent clinical findings in patients with AD and addressing dietary intake as well as physical activity to maintain muscle mass are important clinical strategies which require further investigation (Poehlman, et al., 2000). Also, studies of psychogeriatric patients illustrate significant short term improvement in cognitive function as physical activity appears to have some arousal effect in these patients (Netz, et al., 1994).

7.4. Diabetes

Resistance training represents an alternative to endurance training for patients with type 2 diabetes (Willey, et al., 2003). Very few studies have been conducted but those that have show that strength training is effective in improving insulin sensitivity in patients with Type II diabetes (Castaneda, et al., 2002; Cuff, et al., 2003; Dunstan, et al., 2002; Holten, et al., 2004; McGavock, et al., 2004). These improvements are often achieved using three sessions per week of thirty minutes of leg exercises (Castaneda, et al., 2002; Holten, et al., 2004). It does appear that including resistance training is a viable method of improving body composition and glucose homeostasis in older, obese adults with type II diabetes (Willey, et al., 2003). Dunstan, et al. (2002) showed that high-intensity resistance training (75-85% 1RM), in combination with moderate weight loss, was effective in improving glycemic control in sedentary older men with type II diabetes (aged 60-80 yrs). Given the increasing prevalence of diabetes, resistance training provides an alternative method of improving insulin sensitivity and metabolic function, and may be more appropriate for certain individuals who possess physical limitations to completing aerobic exercise.

7.5. Other

Several other populations are now being studied to determine the efficacy of resistance training for exercise rehabilitation. A recent study assessed the effects of high intensity and/or balance training for patients with Parkinsons Disease (Hirsch, et

al., 2003). The high intensity resistance training increased lower-extremity strength by 52% and 9% with balance-only training (10 weeks of training, 3 sessions per week). In addition balance training improved performance in the summary balance measures and concurrent resistance training enhanced these improvements. These changes also persisted for four weeks following the training intervention. Resistance training has also been shown to be a useful adjunct for patients with chronic renal insufficiency by offsetting the catabolism associated with a low protein diet (Castaneda, et al., 2001). Patients increased muscle fiber size and also maintained bodyweight compared to the control group. It has been suggested that in many cases, resistance training may be more appropriate for older obese adults (Kennedy, et al., 2004). Resistance training is well tolerated by even the oldest-old with a recent study finding no adverse effects in a group of 86-95 year old women (Bruunsgaard, et al., 2004).

Regular exercise has been demonstrated to have significant psychological effects on elderly (Blumenthal, et al., 1999; Singh, et al., 2001). Singh, et al., (2001) showed the anti-depressant value of resistance exercise in older adults. Following ten weeks of supervised resistance training the subjects had significantly reduced Beck Depression Inventory and following an additional ten weeks of unsupervised training there was maintained antidepressant effectiveness.

Muscular strength has recently been shown to be independently associated with the prevalence of metabolic syndrome in men (Jurca, et al., 2004). It also appears that muscular strength adds to the protective effects of increased cardiorespiratory fitness against metabolic syndrome in overweight and obese men (Jurca, et al., 2004). These findings again highlight the importance of including resistance exercise as part of an overall program to improve health in older people.

8. Resistance Training Guidelines for Older Adults

Several position papers are available that clearly outline the basic training principles inherent in resistance exercise (Kraemer, et al., 2002; Kraemer, et al., 2004; Pollock, et al., 2000; Singh, et al., 2002). The key factor to successful resistance training for any population is appropriate program design.

Despite this there is limited research available that has directly investigated different variables of exercise prescription in the elderly (Campbell, et al., 2002; Izquierdo, et al., 2003; Izquierdo, et al., 2004; Newton, et al., 2002; Seynnes, et al., 2004; Taaffe, et al., 1999).

On the basis of available evidence, it appears prudent to include high-velocity, low-intensity movements to maintain structure and function of the neuromuscular system (Bean, et al., 2002b; Newton, et al., 2002). Although it is related to strength, power is a separate entity that may exert a greater influence of physical performance. Specifically the ACSM position stand (Kraemer, et al., 2002) recommends "*the performance of both single- and multiple-joint exercises (machine-based initially progressing to free weights) for one to three sets per exercise using light to moderate loading (40-60% of 1 RM) for 6-10 repetitions with high repetition velocity and training to improve muscular strength*". Further long-term controlled trials are required in older populations to determine the relationship of training variables such as volume and health benefits of resistance training. This position stand may be somewhat conservative as many research studies have shown great benefit with no adverse events using much higher loading (Häkkinen, et al., 2002; Newton, et al., 2002; Sharman, et al., 2002).

A variety of modes of resistance training have been used in training studies. It does appear that the intensity of the program is an important factor for increasing strength and functional status. The issue of intensity of resistance exercise is an important one for any population. According to some studies it appears that high intensity training results in larger improvements in strength and functional capacity in older populations (Seynnes, et al., 2004). A recent study showed that in older men (mean age 81yrs), high intensity resistance exercise (80% 1RM) resulted in greater increases in strength and endurance compared to a low intensity group (Seynnes, et al., 2004). It should be noted that this was supervised training. It may be that low intensity training does not provide a sufficient stimulus for strength and power increases and subsequent changes in functional status in older populations. However other researchers have observed similar changes using different intensities of resistance exercise

(Hortobagyi, et al., 2001; Vincent, et al., 2002b). In older individuals it seems likely that the loading continuum of resistance over the existing motor unit array is tighter and thus differences in the resistance load are small. Thus the load older people use for a 5RM is not much different from a 10RM as the resistance maximums are compressed over a shorter range due to just less robust motor unit array. This could partially explain why older subjects in some studies have benefited from different intensities of training.

In addition, the issue of training volume (eg. number of sets completed) has received little attention from researchers using older populations (Taaffe, et al., 1999). For older women, they may need to train more than two days a week as they do not seem to hypertrophy in the same manner as men, most likely due to more type I muscle fibres and few II fibres (Häkkinen, et al., 2002). While this issue has not been specifically addressed in the research literature, principles of specificity of training indicate that exercise selection should emphasize functional movements which approximate tasks of daily living and address identified limitations to function, mobility and independent living such as hip, knee and ankle extensor strength and power.

Clearly further research is required to determine the relationships between variables such as training volume and intensity, and changes in functional status and health outcomes. This will provide a more adequate basis for scientific exercise prescription in these populations.

9. Summary and Conclusions

The large numbers of studies that have been conducted investigating resistance training by older adults suggest that people need to include activities that increase muscular strength and power. It is clear that resistance training results in improvements in some aspects of functional status, in addition to increasing muscular strength, power and muscle mass. There is also increasing evidence that supports the theory that a threshold level of strength may be required to perform basic activities of daily living and to participate in activities designed to maintain cardiorespiratory fitness (Brill, et al., 2000). There is also increasing evidence of the central role of skeletal muscle pathology significantly contributing to decreased exercise capacity seen in certain disease

conditions (Pu, et al., 2001). Therefore resistance training programs, as they specifically target the peripheral and trunk skeletal muscles should provide a potential treatment for many of these conditions. The public health benefits of incorporating resistance training programs are clear. For example, the potential decreased risk of falling and less likelihood of sustaining fall related fractures are an enormous potential benefit. However, larger clinical trials are required to confirm the potential benefits of resistance exercise for functional status in older adults.

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