PEOPLE 65 YEARS OF AGE AND older represent the fastest growing segment of the population in North America. In 1900, only about 4% of the U.S. population was 65 and older. In contrast, 20% of Americans will be age 65+ by the year 2030 (5). At the same time, the health status among older people is gradually improving (16). Many are both able and motivated to keep fit and mobile, as reflected by an increase in the number of older men and women participating in physical activities (23).

This article evaluates the effect of aging on muscular function and discusses potential benefits of resistance training for older people. Guidelines for establishing appropriate resistance training protocols for older people are also provided.

Effects of Aging

Muscle Size

There is some disagreement as to when muscle begins to atrophy and at what rate this occurs. But there is no doubt that the aging process has a deleterious effect on muscle mass. At first glance the decrease in muscle mass with aging appears similar to the atrophy that occurs with a decrease in physical activity. Most studies have found that activity levels are inversely related to age (1). Thus it remains uncertain how much loss of muscle function is an inevitable consequence of aging and how much is due to an age related decrease in physical activity (1, 4, 14).

When there is a decrease in physical activity, such as occurs when a limb is put in a cast, the muscles will atrophy. This atrophy results from a decrease in the cross-sectional area of individual fibers, not a decrease in the total number of fibers.

For young people, muscle atrophy is reversible and muscle mass and cross-sectional area (CSA) are restored when normal activity levels are resumed. In contrast, the muscle atrophy that occurs in old age appears to involve some loss of muscle fibers and therefore is not completely reversible (1).

The rate of atrophy occurs in two distinct phases (2). Muscle CSA reaches a peak between the ages of 16 to 19 for females (22), and roughly between 18 to 22 or 18 to 24 years of age for males. Between the ages of 24 to 50, muscle mass declines from 5 to 10% overall (2). After the age of 50, however, muscle atrophy accelerates so that between 50 and 80 years of age an additional 30% of total muscle CSA is lost (2), though some researchers (4, 16, 23) suggest the total loss in muscle mass is only 25–30% by 60 to 70 years of age.

Regardless of how much muscle mass is lost and at what rate, the result is progressive weakening and impaired mobility (16). It has been determined that older people can activate their muscles at or near maximum.
This supports the belief that the primary reason for the age related decline in strength is a reduction in muscle volume and mass (23).

The cause of this increased rate of muscle atrophy after the age of 50 is unknown. It could be attributed to a decrease in total number of fibers, a decrease in the dimensions of individual fibers, an impairment of excitation/contraction coupling, and/or decreased activation of high threshold motor units (1).

A reduction in the number of motor units could also play a role in this age related atrophy (2). The number of motor units is fairly constant from ages 10 to 60, although it has been reported that motor unit loss seems to begin when people are in their 50s. After the age of 60, entire motor units cease to function. Thus it has been suggested that this reduction in muscle mass is a result of both failure of the nerves to reinnervate the muscle fibers during degeneration/regeneration, and of motor neurons not regenerating (2).

Interestingly, it appears that strength and muscle mass in older persons are better maintained in the upper body than in the lower body (1, 22). It has been suggested that much of the difference in the rate of aging on muscle function between the arms and the legs is due to the persistence of faster and more forceful contractions in the arms.

Some researchers suggest that aging leads to a selective loss or atrophy of fast-twitch fibers (1, 2). In persons over 70, the mean area of Type I fibers decreases by 15–20% while the percentage of Type II fibers decreases by as much as 40%, according to needle biopsy specimens. These biopsies reveal only minor changes in either muscle fiber size or the ratio of Type II to Type I fiber areas in the vastus lateralis until the 7th decade of life.

For persons over age 70, however, there is a progressive reduction in the area of muscle fiber occupied by Type II fibers, particularly Type IIB (2). The decrease in proportion of Type II fibers could be the result of either their conversion to Type I fibers or to a direct loss in total numbers of Type II fibers (4).

One explanation for the changes in proportion of Type I and Type II fibers is a loss of terminal sprouting, with resultant axonal withdrawal (1). Fiber-type conversion could thus occur if Type II fibers were reinnervated by the sprouting of the nerve terminals that normally innervate Type I fibers. Terminal sprouting is a normal process of endplate repair and reconstruction throughout life, but the capacity of this process deteriorates in older people (1).

This inference of Type II fibers being converted to Type I is further supported as a result of (a) the enlargement of motor unit size with aging and (b) muscle fibers in a given area of the muscle becoming more homogeneous in fiber type (i.e., fiber type grouping). This change in fiber type arrangement with aging is thought to mean that a neurogenic process is likely to be one of the main contributors to the age related reduction in muscle volume (2, 22).

Muscle Strength
As already noted, there is a gradual loss of muscle mass with aging. The loss of static and dynamic strength occurs at about the same rate as the age related decrease in overall lean tissue mass (4, 22). This suggests a causal relationship between weakening of the muscle and its decrease in mass (12). However, the loss of strength and tissue mass could reflect a decrease in fiber number, a decrease in average fiber size, or both (1).

Similar to the loss in muscle mass, there is some disagreement as to the age and rate at which strength levels begin to decline. Peak strength levels occur at about age 20 in women, whereas men have a plateau in peak strength from maturity through approximately age 30, after which there is a gradual decline (6, 22). After the age of 50, however, muscle atrophy accelerates so that between 50 and 80 years of age an additional 30% of total muscle CSA is lost . . . though some researchers . . . suggest the total loss in muscle mass is only 25–30% by 60 to 70 years of age.

According to Clarke et al. (6), strength levels are relatively well maintained between the ages of 30 and 50. But Wilson (22) suggests that strength levels remain relatively stable only until the ages of 35–40 and then gradually decrease.

These reductions in strength levels continue so that between 50 and 70 years of age a 15% loss in muscle strength occurs per decade. Between 70 and 80 years of age, strength losses of 20 to 40% have been noted (2, 23). Very old individuals show strength losses up to 50% or more (23), as revealed by surveys in the U.S. The
surveys have shown that after the age of 74, some 28% of men and 66% of women cannot lift objects weighing more than 4.5 kg (10).

As is the case with decreases in muscle mass in older people, researchers are trying to determine to what degree strength loss is a function of aging and to what degree it is due to lack of use (10, 14). In a study evaluating the results of resistance training in subjects 50 and older, it was found that by age 50 both active and inactive subjects had greatly decreased lean body mass and muscle function.

The researchers concluded that persons engaged in strength training maintained higher levels of strength and endurance than those who were inactive, but both functions show signs of deterioration by 50 years of age (22). Thus at least part of the loss in strength in older persons appears to be a function of aging.

The size of a muscle and its force production capabilities are related. Thus, some factors involved with muscle atrophy in the elderly also contribute to the loss of strength that comes with aging. As noted, the number of motor units decreases, as does the ratio of Type II to Type I fibers. Because the number of motor units and fiber type both play an important role in force production (19), it follows that strength levels would also decline.

Hormones also play a role in muscle strength. It has been found that as people age, their bodies make less testosterone and less growth hormone. The decrease in testosterone may be a factor in the diminished capacity for hypertrophy in older men (3). Both testosterone and human growth hormone are anabolic hormones that help maintain muscle mass (14).

Interestingly, it has been found that older people maintain eccentric strength better than either isometric or concentric strength (23), though the mechanism by which aging muscle maintains eccentric strength is not clear. It has been suggested that hormonal factors may affect crossbridges during shortening or isometric action, but not during lengthening contractions.

### Benefits of Resistance Training in Older Persons

The health benefits of physical activity and exercise on a regular basis have been well documented since the 1960s. However, information specifically evaluating the health benefits of exercise in older persons is incomplete (7). Following is a brief discussion of some benefits of resistance training for that population.

**Strength Gains**

Several studies (7, 10, 17, 23) have demonstrated that older people are capable of increasing strength if they participate in resistance training. For example, Young and Skelton (23) found that healthy women ages 75 or more increased isometric quadriceps and biceps strength 13-30% after 12 weeks of training. A study by Pratley et al. (17) involving men 50-65 years of age found a 40% increase in total body strength following 16 weeks of strength training.

Drought (7) cited a study in which 10 frail, institutionalized volunteers of both genders, age 90 ± 1 yr, showed an average increase in strength of 174 ± 31% after 8 weeks of training. And a study involving 12 men ages 60-72 years found marked improvements in dynamic strength after 12 weeks of training (10).

**Muscular Hypertrophy**

It has been widely accepted that strength gains in older individuals are due to improved neural recruitment patterns rather than to hypertrophy of muscle fibers. This is similar to conclusions drawn from studies evaluating strength gains in women (12). However, when sensitive techniques are used, such as fiber area muscle biopsy or cross-sectional area by CT scan, it appears that hypertrophy is responsible for some of the strength gains observed in older persons.

The importance of sensitive measurements to determine changes in body composition in older individuals was also noted by Treuth et al. (21). When sensitive measurements are used, they can detect strength-training increases in the cross-sectional area of muscle in older individuals.
Studies show that even persons in their 90s can achieve muscle hypertrophy with standard progressive resistance training techniques (1). This is in agreement with Munnings (14), who notes that research suggests older people can gain lean tissue, muscle mass, and strength from resistance training. These adaptations in muscle protein occur as a result of an increased rate of protein synthesis.

The changes occur rapidly, within 2 or 3 weeks of beginning a resistance training program, according to several researchers (2, 7, 10, 18). Drought (7) cited a study in which 7 subjects 90 years of age had CT scans pre- and posttraining. Muscle area increased $14.5 \pm 7.8\%$ in the quadriceps and $10.6 \pm 9.1\%$ in the hamstrings and adductors after 8 weeks of training.

Further, individuals 60–90 years of age have been found to increase or maintain muscle mass with resistance training (2). A study involving 12 subjects ages 60–72 found an increase in thigh cross-sectional area over 12 weeks of training, from 9.8 to 11.4\% for the right and left hamstrings, and from 11.9 to 9.3\% for the right and left quadriceps, respectively. Muscle biopsies revealed a progressive increase in fiber area with training. By Week 12 the area of Type I fibers had increased by 33.5\% and the area of Type II fibers by 27.6\%. The ratio of Type II to Type I fibers remained unchanged (10).

This suggests that a lack of muscle loading could contribute to muscle atrophy in older persons. As evidence of this, men in their 70s who had participated in resistance training since before age 50 demonstrated muscle CSA and strength comparable to a group of 28-year-old sedentary subjects (23).

### 7 Benefits of Resistance Training for Older Persons

1. Studies have found that weight training can induce dramatic increases in muscle strength in older persons.

2. Sensitive measurements have revealed that some of the strength gained through weight training is due to muscle hypertrophy, as is the case with younger adults.

3. The increase in body fat associated with aging can be reversed through resistance training. It increases lean body mass, which in turn elevates resting metabolic rate and burns fat.

4. Besides increasing muscle strength, strength training increases the strength of tendons and ligaments, resulting in better protection for the muscles and reducing the physical frailty of old age.

5. Resistance training improves mobility in older persons by improving strength so they can better carry out their everyday tasks.

6. Resistance training reduces bone loss, which is especially important for postmenopausal women because the decrease in estrogen can lead to osteoporosis.

7. Exercise tends to improve mood and general well-being, and it is believed that exercise can yield psychological benefits in older persons.

### Reduced Body Fat %

Aging is associated with a loss of fat-free mass and an increase in body fat. The loss of fat free mass is a result of decreases in bone mass, skeletal muscle mass, and body water (21). Resistance training can have a positive effect on decreasing both total and regional fat tissue mass. It was found that after 16 weeks of resistance training, body fat dropped from 26.6 ± 6.0\% to 24.8 ± 6.3\% and fat mass dropped from 23.8 ± 7.9 kg to 22.1 ± 7.7 kg. In addition, fat free mass increased from 61.3 ± 7.8 kg to 63.0 ± 7.6 kg (15).

Resistance training has a relatively low caloric cost. Therefore significant decreases in both total and regional fat mass cannot be explained on the basis of energy expenditure from the training program. However, resistance training can increase lean body mass. An increase in lean body mass will have the effect of elevating resting metabolic rate. This increase in resting metabolic rate could help explain the discrepancy between the caloric expenditure of resistance training and the actual fat loss (10).

Regardless of the mechanism, these results suggest that strength training may play an important role in the prevention of age-associated losses of strength and muscle mass, as well as the deposition of body fat, which may be related to the declines in functional ability and health status in older people (21).

### Reduced Frailty

Physical frailty describes the combined effects of muscle atrophy, declining strength and power lev-
els, fatigue, and injury. Although physical frailty is commonly accepted as a normal aspect of aging, its causes are unknown. It is recognized that conditions such as diabetes and obesity, which occur at higher rates in older people, contribute to this frailty.

The degree to which these changes are preventable and treatable is not clear. Decreases in muscle mass, strength, and power may be related to reduced activity levels throughout life. Yet remaining physically active does not appear to completely protect skeletal muscles from age-related decrements (4).

However, as just discussed, older participants in resistance training programs do show significant increases in both muscle mass and strength. Increases in muscle size and strength reduce the effects of frailty because stronger muscles can better protect the joints they cross. Strength training may also increase the strength of tendons and ligaments, in turn reducing the possibility of strains, sprains, and other injuries that accompany physical activity (20).

Other conditions such as diabetes, high blood pressure, and risk of or recovery from heart attack can all be positively affected by exercise. In these situations, advice regarding any exercise program is the responsibility of the physician treating the individual and this advice must be strictly adhered to.

**Improved Mobility**

All body movements are produced by contractions of skeletal muscles. With increasing age, as noted, skeletal muscle gradually decreases in volume and hence strength. Any loss in the functional properties of skeletal muscle will result in some degree of immobility (16). A loss of mobility inhibits participation in physical activities as well as successful participation in everyday activities (4, 8).

One important aspect of resistance training in older people is that maintaining or improving strength allows them to better carry out their routine tasks. Good cardiorespiratory function is important, of course, but many clinical problems physicians see in that population are more related to muscle weakness than to a lack of aerobic fitness.

An inability to get out of a chair, rather than an ability to run across the street, is more likely to limit the quality of life for older people (7). For example, an 80-year-old may require more than 100% of his or her quadriceps strength just to get up from a chair. Many older people reach the point at which they can no longer lift themselves out of bed or off a toilet seat. This may lead to a need for constant assistance and sometimes to institutionalization (7).

Resistance training helps improve mobility among older persons (14). Increases in gait velocity (11%), stair climbing power (28%), and spontaneous physical activity (34%) following resistance training have been shown in nursing home residents 72–98 years of age (16).

It should be noted that while all of these values were statistically significant, the absolute changes in gait velocity were not large. However, when older individuals can continue to be self-sufficient and mobile, this greatly reduces their dependency on others and the need for institutionalization.

**Reduced Bone Loss**

Investigators have begun evaluating the relationship between bone loss and exercise. Although the relationship is not well understood, most researchers encourage the use of resistance training as a method to prevent or reduce the effects of osteoporosis (14). This is especially important in postmenopausal women, because of a decrease in estrogen levels, have increased losses in bone density. Since a contributing factor to osteoporosis is a lack of weight-bearing exercise, it follows that resistance training would help combat osteoporosis.

In this regard, it is important to note that the benefits of exercise last only as long as one maintains the program, and that exercise alone cannot prevent or cure osteoporosis.

**Psychological Benefits**

Aging is also accompanied with decreases in neuropsychological functioning, memory, and intelligence. But many older adults experience no more—and perhaps even less—emotional distress than young adults. If they are physically able, older people possess comparable psychological vigor to be active (5).

Several studies have indicated a positive relationship between physical activity and psychological well-being. A relationship has been found between physical inactivity and depression (5). On the other hand, exercise is associated with decreased symptoms of depression, anxiety, and despair in the general population.

In addition, exercise is positively related to improved mood, general well-being, and relatively infrequent symptoms of anxiety and depression. Thus it has been proposed that the benefits of physical activity for an aging population are both physiological and psychological (5).
But while there is some experimental evidence that physical activity is causally related to enhanced psychological well-being in older persons, further research is needed. Additionally, given the lack of well-controlled studies and the equivocality of the available data, it would be premature to conclude that exercise leads to enhanced mental health in older persons (5). Indeed, some studies indicated no benefit from exercise in terms of psychological well-being.

It must be recognized that exercise is individual and situation-specific. There have been relatively few cross-sectional or longitudinal studies comparing the effects of physical activity on the psychological well-being of young vs. older individuals.

A few studies have evaluated the effects of chronic exercise on the psychological well-being of older subjects, but the results have been mixed. This may be, in part, because most training studies involving older subjects have some of the same methodological weaknesses as seen in studies on young or middle-aged subjects. In addition, few researchers have evaluated the effects of a single exercise session on the psychological well-being of older individuals.

Additionally, only a few studies have evaluated the effects of acute or chronic exercise on older patients with clinical problems (5). Thus there is a real need for exercise scientists and researchers in the area of aging to conduct well-controlled studies evaluating the relationship between physical activity and psychological well-being in older people so that definite conclusions can be drawn as to the relationship between exercise and mental health.

## Program Design for Older People

Knowledge of the neuromuscular system and its response to training in older people is necessary if physicians, physiotherapists and certified personal trainers/ strength and conditioning specialists are to give the best possible advice and plan optimal exercise programs for this population (23).

It appears that the risks of resistance training in older populations are less than previously thought. However, before an older person begins a resistance training program, he or she should get a thorough medical examination so that any potential problems can be identified. This is particularly important for persons with high blood pressure or other conditions that can lead to short-term elevation in BP (22).

It is important to realize that some resistance training exercises such as maximum squats, deadlifts, and leg presses result in extremely high BP values. Similarly, isometric exercises can also result in large BP increases and therefore should be avoided by anyone who has a medical history of high blood pressure or a susceptibility to high BP related illnesses.

Many of the risks of resistance training can be avoided by stressing proper training guidelines (7):

1. **The program should concentrate on a few major muscle groups of the body (e.g., knee extensions, hip extenders, elbow extenders).**
2. **A contributing factor to osteoporosis is a lack of weight-bearing exercise, thus there should be an emphasis on weight-bearing exercises.**
3. **The order of exercises should progress from large to small muscle groups (e.g., thigh exercises before chest exercises).**
4. **Dynamic contractions are preferable to static or isometric contractions, both of which should be avoided.**
5. **Resistance training exercises should be performed slowly and in good form, through the joint’s entire range of motion; no swinging or bouncing.**
6. **Each muscle group to be trained should be warmed up thoroughly; the warm-up session should last 10 min.**
7. **Each exercise should be performed for 8–12 reps or until failure.**
8. **Proper breathing rhythm is important, especially in older people. Exhale while lifting, inhale while slowly lowering the weight. There should be no breath holding because this can elevate BP.**
9. **Each exercise should be performed for 2 to 3 sets as the individual becomes conditioned to multiple sets. The weight should be increased to keep an approximate load of 80% of 1-RM.**

The actual program used for older people is not much different from those for younger people (14). However, recovery periods between training sessions may need to be longer for older persons. Studies have reported that older subjects tend to have more training-induced soreness than younger individuals, who typically require 2 to 3 days of recovery between resistance training sessions of the same muscle group. An older individual may need 3 to 4 days to allow for adequate recovery (22).

Another adjustment might be that when beginning a training
program, the older individual may be at a relatively low level of strength. Because of this, he or she should employ correspondingly low training intensities and workloads.

There is some disagreement as to what type of equipment should be used when training older persons. Some believe free weights are better because many of the exercises are performed while standing. The action of the muscles as they work to stabilize the upright body may help to build bone strength. In contrast, others say one advantage of machines is that they provide back support. Machines also predetermine the range-of-motion track, which may be good for beginners (13).

Performing free-weight exercises requires more knowledge of proper technique. Some feel the goal should be to work toward using free weights because free-weight exercises help develop balance and coordination as well as strength (8, 9, 11, 14). Thus, training should begin with machines. As the individual develops a strength base and more confidence, the emphasis can gradually shift to free-weight training.

# Resistance Training and Injuries

Information on the rate of injury during exercise training in older persons is lacking. Pollock et al. (15) evaluated the rate of injury in 57 older men and women participating in exercise programs. The subjects, all in their 70s, were divided into 3 groups: walk/jog (n = 21), strength training (n = 23), or control (n = 13).

The walk/jog group trained 3 times a week for 26 weeks. At first they walked for 30 min at 40-50% of max heart rate. Gradually the duration and intensity were increased so that by the 26th week the subjects were exercising at 75-85% of heart rate reserve for 35-45 min. This intensity was accomplished by alternating moderate- and fast-paced walking intervals or walk/jog intervals.

Training for the strength group also consisted of 3 sessions a week for 26 weeks. The program consisted of 1 set of 10-12 reps on each of 10 variable resistance machines. The goal of the first 13 weeks was to learn correct form and technique. Subjects used moderate weights and completed 10-12 reps of each exercise but were not required to work to muscle failure. After retesting in the 13th week, the intensity of the training was increased and subjects were encouraged to complete each exercise to muscle failure. Resistance was increased by approximately 5% when the subject could complete 12 reps of a given exercise.

Subjects were considered to have incurred an injury if training had to be stopped or significantly altered for at least 1 week. Minor muscle soreness was not considered an injury.

During training, only 2 of the 23 strength training subjects sustained an injury (8.6%), both of which were unrelated to any previous musculoskeletal problem. However, 9 of the 21 walk/jog subjects sustained an injury (42.9%). Only 1 of these 9 injuries occurred during the first 13 weeks of training; the other 8 occurred when training intensity was increased. All injuries involved the lower extremity.

The lower injury rate in strength training was probably related to several factors (15). First, although subjects often trained to volitional fatigue, the intensity of training for any given repetition was less than for 1-RM testing. In addition, the subjects were not required to work to maximum fatigue during the first 13 weeks of the program. This protocol allowed a more gradual adaptation to the demands of strength training.

It was pointed out that while studies using previously active men found no muscle or joint problems, eccentric actions have been shown to produce muscle damage, from which older subjects seem to recover more slowly (15). Training and testing involving eccentric actions should certainly be included in a program, but it must be done with caution (23).

# Summary

People 65 years of age and older represent the fastest growing segment of the population in North America. Resistance training offers numerous health benefits for this population.

By age 80, total muscle CSA may be reduced by 40% and strength levels by 20 to 40%. Many studies have shown that older people can increase their strength as a result of resistance training. A high-intensity weight training program can induce dramatic increases in muscle strength in frail men and women in their 90s. Fiber area muscle biopsy and cross-sectional CT scans have shown that some strength gains in older people are due to muscle hypertrophy. It has also been shown that resistance training can help decrease both total and regional fat tissue mass.

Physical frailty, the combined effect of muscle atrophy, declining strength and power, and fatigue and injury are accepted as normal aspects of aging. Resistance training can have a positive effect on frailty by increasing the strength of the muscles, tendons, and ligaments and reducing the opportunity for injury.
Resistance training helps improve mobility among older people. When they can continue to be self-sufficient and mobile, this greatly reduces their dependency on others and the need for institutionalization.

Exercise has been shown to help reduce bone loss. Although the relationship between exercise and decreased bone loss is unclear, most researchers encourage resistance training as a method of preventing or reducing the effects of osteoporosis, especially for postmenopausal women.

If physically able, older people possess the psychological vigor to be active. Studies have indicated a positive relationship between physical activity and psychological well-being. It has been shown that there is a relationship between physical inactivity and depression.

Many of the risks of resistance training can be avoided by stressing proper training guidelines. Programs designed for older persons need not be much different than those for younger people.

**References**


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