THE HEALTH BENEFITS OF regular participation in physical activity and exercise have been well documented in scientific studies since the 1960s (7). However, information specifically targeting elderly persons is still relatively incomplete. It is widely accepted that, in a variety of populations, regular exercise is a beneficial component in helping to prevent and treat cardiovascular disease (22), coronary heart disease, osteoporosis, diabetes, hypertension, and depression (14). This information certainly has important implications for elderly persons who wish to maintain or improve their health.

While much research on the health benefits of exercise has focused on cardiovascular exercise activities (5), an increasing number of studies show that resistance training offers many health benefits to the general public (30). Although fewer studies have been conducted using resistance training in elderly populations, it appears that resistance training for the elderly can be both beneficial and safe—even for persons 90 years of age (10).

**Importance of Strength to the Elderly**

In February 1992 the U.S. House Select Committee held a hearing on aging called “Aging Research: The Benefits Outweigh the Costs.” Chairman Edward Roybal pointed out that the 85+ age group is growing six times faster than the rest of the population, and that health care spending will become even more of an important issue in the next 50 years. During this hearing it was also pointed out that the nation could save $4 billion a year by simply postponing for 1 month the types of severe disability, such as broken hips from falls, that lead older persons to be placed in nursing homes (23).

Maintaining or improving strength is important for the elderly because they need adequate strength to carry out many routine tasks of everyday living. Although the maintenance of cardiovascular function is important, many clinical problems that physicians see in the elderly are more often related to muscle weakness than to lack of aerobic fitness. An inability to get out of a chair—not the inability to run across the street—is more likely to limit the quality of life for the elderly (31).

For example, an 80-year-old person 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, and therefore may need constant assistance, which in turn may lead to institutionalization.

Injury due to falls is a leading cause of morbidity and mortality in the elderly population (2, 20). Approximately 40% of persons over age 65 fall at least once a year, and persons 85 years and older may be more likely to die from falls and hip fractures than from heart disease. Many such falls can be prevented by an increase in muscular strength (31).

For these reasons, researchers have begun to emphasize the importance of resistance training to...
increase strength in the elderly population. A major goal of strength training should be to conserve or obtain enough muscle function to last a lifetime. When elderly individuals can continue to be self-sufficient and mobile, this greatly reduces their dependency on others and the chance of institutionalization. With increased muscular strength, there is also less chance of life-threatening falls and injuries (31).

■ Aging and Strength Loss

In general, strength losses with age may vary from 20% in early adulthood to 40% by age 70 (26). A decline in muscle strength is one of the more predictable features of aging. However, the contributions of biological aging, cumulative diseases, inactivity, and poor dietary habits toward this inevitable decline are unclear (10).

**A Look at One Recent Study**

One study that has been quoted repeatedly, not only by the health industry but also throughout the mass media, is the Fiatarone et al. 1990 study (10), "High-Intensity Strength Training in Nonagenarians." The results of this study were exciting not only because of what they demonstrated but also because the study seemed to contradict some long-held myths about resistance training and the elderly.

The safety and efficacy of high-resistance strength training had been demonstrated previously in healthy older men (11). However, a similar intervention using frail institutionalized elderly men and women had never been conducted. Because muscle weakness in frail elderly has been linked to recurrent falls, and these falls are a major cause of morbidity and mortality in the elderly population (2, 22), the Fiatarone et al. study (10) has particular clinical relevance.

**Training protocol.** Ten frail, institutionalized volunteers of both sexes, age 90 (±1 yr), were enrolled in the study. Reasons for exclusion of other individuals wanting to participate included recent myocardial infarction or fracture, behavioral disturbance, and severe arthritis. Among the 10 volunteers chosen, the most common medical diagnoses were that 7 had osteoarthritis, 6 had coronary artery disease, 6 had an osteoporotic fracture, and 4 subjects were hypertensive.

An initial one-repetition maximum (RM) was used to set the load for the 1st week of training, which was to be set at 50% of the 1-RM. The 8-week training protocol involved concentric/eccentric isotonic progressive resistance training on a leg extension machine to measure and train quadriceps strength. Subjects trained three times a week and performed three sets of 8 repetitions with each leg.

By the 2nd week the load was increased to 80% of the one-repetition maximum. The 1-RM was remeasured every 2 weeks and the training stimulus was adjusted to keep the load at 80% of the new 1-RM. Rest periods between sets were from 1 to 2 min.

... muscle weakness in frail elderly has been linked to recurrent falls,...

... a major cause of morbidity...

**Tolerance of training regimen.** Nine of 10 subjects completed the training protocol. Blood pressure and pulse rate varied little (systolic blood pressure <10 mm Hg, pulse rate <5 bpm) during the training sessions.

**Muscle strength.** The average strength gain at 8 weeks was 174 ± 31%. No differences were noted between men and women.

**Muscle size.** Seven subjects had CT scans before and after training; muscle area increases were 11.7 ± 5.0% (total), 14.5 ± 7.8% (quadriceps), and 10.6 ± 9.1% (hamstrings and adductors). Strength gains did not correlate with these changes in muscle size by CT scan.

**Clinical outcomes.** Changes in functional mobility accompanied the improvement in muscle strength and size. Tandem gait walking speed increased from 13.8 cm per sec to 20.4 cm per sec. Two subjects who used walking canes before the study no longer needed them, and 1 of 3 subjects who could not rise from a chair without use of the arms now was able to do so.

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Detraining effects. In 7 of the 9 subjects who completed the study, 1-RM testing was repeated after 2 and 4 weeks of detraining. In these subjects, dominant quadriceps strength declined from a peak of $136 \pm 16\%$ above baseline at Week 8, to $115 \pm 23\%$ at Week 10, to $92 \pm 23\%$ at Week 12. Thus a significant 32\% loss of maximum strength increase was seen after only 4 weeks of detraining. It should also be noted, however, that even after 4 weeks of detraining the subjects were still almost twice as strong as they had been before they started training.

Comments
The major finding in this study was that a high-intensity weight training program can induce dramatic increases in muscle strength in frail men and women up to 96 years of age. The lower extremity strength increase ranged from 61 to 374\% over baseline, with subjects demonstrating up to a fourfold increase in as little as 8 weeks. Because muscle strength decreases by perhaps 30 to 40\% during the course of the adult life span (26), it is likely that at the end of training these subjects were stronger than they had been for years.

This potential for a reversal of age related muscle weakness remains unexploited. Despite the evidence from studies of younger individuals that muscle will hypertrophy and show large gains in strength in response to high loads (>40\% of maximum) (8, 28), there has been reluctance to apply this principle to the training of older individuals.

The number of repetitions performed seems to have a major influence on strength gains achieved. Low to moderate resistance training has produced little or no increase in strength in older subjects, as seen in the reports of Aniansson and Gustafsson (1), Larsson (16), and Hagberg et al. (13).

There is only one published report of dynamic strength gains in older subjects after high-intensity weight training. In that study, by Frontera et al. (11), strength increased by an average of 107\% in the knee extensors and 227\% in the knee flexors after 12 weeks of training in a group of healthy men 60 to 72 years of age.

...even individuals in their 90s can achieve muscle hypertrophy with standard progressive resistance training techniques.

It has been widely believed that strength gains in older subjects are due to improved neural recruitment patterns rather than to hypertrophy of the muscle fibers. This is based primarily on animal studies that show an age related decrement in exercise-induced hypertrophy in the rat (13), as well as the finding that no muscle hypertrophy (estimated anthropometric measurements) accompanied the strength gains in the older men studied by Moritani and devRies (17).

However, when more sensitive techniques are used, such as fiber area muscle biopsy (1, 11, 16) or cross sectional area by CT scan (11), muscle hypertrophy seems to account for a portion of the strength gains observed in the elderly. Similarly, this study showed that even individuals in their 90s can achieve muscle hypertrophy with standard progressive resistance training techniques.

Strength gains observed in this study were also attributed to improved neural muscle fiber recruitment patterns. As has been noted in previous studies (11, 17), no direct correlation was found between the degree of hypertrophy and the relative strength gains in the subjects. Some strength gains occurred within 2 weeks, before hypertrophy would have been a factor.

The training regimen was well tolerated despite the underlying medical conditions of the subjects. Cardiovascular complications were not seen, and because of the slow pace of the exercise, only insignificant variation in pulse rate and blood pressure was observed. No exacerbations of underlying degenerative joint disease occurred in the 7 subjects with that diagnosis. It is particularly interesting to note that no training or detraining differences occurred between men and women.

Fiatarone et al.‘s Conclusions
Muscle weakness in the frail elderly is a multifactorial phenomenon that has been linked to the high prevalence of falls and immobility in this population (29). Fiatarone et al. (10) demonstrated that high-intensity strength training is associated with significant gains in strength and muscle hypertrophy in individuals up to age 96. However, just as in younger individuals (27), these changes in muscle function are not maintained in the absence of continued training. Therefore, sustained improvement requires an ongoing program of muscle conditioning.

Observations regarding the safety of strength training, even among the frail elderly with underlying cardiovascular disease, should be emphasized because the known hazards of immobility
Pollack et al. (21) did not report any injuries among elderly subjects who participated in strength training activities. However, they did report numerous injuries among joggers, even though these subjects had participated in a walking program for 3 months before starting to jog. Thus the researchers recommend that some older subjects may have to avoid jogging and participate instead in strength training and walking.

**Resistance Training Guidelines for the Elderly**

The following resistance training guidelines for elderly individuals are taken from Guidelines for Resistance Training in the Older Adult, a one-page list of guidelines by Maria A. Fiatarone, M.D., and distributed by the Department of Agriculture Human Nutrition Research Center at Tufts University, Boston (9):

1. Encourage elderly individuals to concentrate on a few important muscle groups (e.g., knee extensors, hip extensors, elbow flexors).
2. Lifting weights (dynamic strengthening) is preferable to pushing against an immovable object (static or isometric strengthening).
3. Instruct older adults to perform the movements slowly, through the entire range of motion of the joint, in good form. No swinging or bounce at the end of the movement.
4. The older individual may want to start with a warm-up of several repetitions with no weight to stretch the muscle group. Resistance used can be commercial weights but don't have to be. Homemade weights and other forms of resistance can include sandbags, large rubber bands, bags, or socks filled with dry beans, laundry detergent bottles filled with water or sand. Laundry detergent bottles can be filled to varying levels to adjust the resistance as needed. Resistance training need not be any more expensive than walking.
5. Each exercise should be performed for 8–12 repetitions until another repetition cannot be performed using good form. Proper breathing rhythm is important for everyone, but especially for older exercisers. Exhale during lifting, inhale while slowly lowering the weight. Make sure there is no breath-holding. Holding the breath during exertion can elevate blood pressure.
6. Exercises should be performed for 2–3 sets each as the individual becomes conditioned enough to tolerate multiple sets. Weight should be increased to keep an approximate 80% of 1-RM load.

**References**


9. Fiatarone, M.A. Guidelines for Resistance Training in the Older Adult. (A guideline sheet distributed by the USDA Human Nutrition Research Center on Aging at Tufts University, Boston).


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