The Benefits of Strength Training for Older Adults

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Abstract: Aging is associated with a number of physiologic and functional declines that can contribute to increased disability, frailty, and falls. Contributing factors are the loss of muscle mass and strength as age increases, a phenomenon called sarcopenia. Sarcopenia can result or be exacerbated by certain chronic conditions, and can also increase the burden of chronic disease. Current research has demonstrated that strength-training exercises have the ability to combat weakness and frailty and their debilitating consequences. Done regularly (e.g., 2 to 3 days per week), these exercises build muscle strength and muscle mass and preserve bone density, independence, and vitality with age. In addition, strength training also has the ability to reduce the risk of osteoporosis and the signs and symptoms of numerous chronic diseases such as heart disease, arthritis, and type 2 diabetes, while also improving sleep and reducing depression. This paper reviews the current research on strength training and older adults, evaluating exercise protocols in a variety of populations. It is clear that a variety of strength-training prescriptions from highly controlled laboratory-based to minimally supervised home-based programs have the ability to elicit meaningful health benefits in older adults. The key challenges as this field of exercise science moves forward are to best identify the most appropriate strength-training recommendations for older adults and to greatly increase the access to safe and effective programs in a variety of settings.
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Introduction

There are currently 33 million Americans aged ≥65 living in the United States; over the next century, that number will more than double, with the greatest increase occurring among individuals aged ≥85.[1] The implications of extended years of life often involve increased incidence of chronic disease as well as the development of functional limitations. Despite the recent reduced prevalence of disability, 7 million older adults still are chronically disabled.[2] Physiologically, there is a loss of muscle mass and strength as age increases. Observational studies indicate that approximately 1% of muscle mass is lost per year after the fourth decade of life.[3,4] This age-related loss of muscle mass is known as sarcopenia.[5] Sarcopenia can result from or be exacerbated by certain medical conditions, yet it remains an issue of concern for the aging population regardless of chronic disease presence. Moreover, the loss of muscle mass and strength with age can increase an individual's risk for developing certain chronic conditions, such as osteoporosis.[6]

Often concurrent with increased physical impairment is the decreased ability to perform functional tasks such as climbing stairs, standing up from a chair, and doing basic household chores, all tasks that require a threshold of muscular strength. In some instances, it is the underlying presence of chronic disease that causes physical impairments; in other cases, it is simply age-related decrements, such as the loss of muscle mass and strength, that lead to these functional limitations. Regardless, this series of events can lead to disability, dependence, and increased morbidity and mortality for older adults.[7]

Research in the last several decades has shown that many of the age-related physiologic decrements older adults experience are not inevitable. The primary components of physical fitness are cardiorespiratory endurance, flexibility, body composition, power, balance/coordination, muscular endurance, and muscular strength. Each component has a role in preserving function, reducing risk for chronic health conditions, and averting disability with age.[8–10] Specifically, studies have now shown that targeted exercise referred to as strength training (also known as weight lifting or progressive resistance training) has the power to combat weakness and frailty and their debilitating consequences.[6] Functionally, strength training is an activity in which muscles move dynamically against weight (or other resistance) with small but consistent increases in the amount of weight being lifted over time.

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Although it has yet to be determined whether the muscle mass, strength, and other benefits gained through strength training can actually prevent disability in older adults, scientific research and community implementation of strength-training programs have shown that it is a safe and effective means by which to improve physical capabilities, reduce risk for falls, prevent functional limitations, and avert the development of certain chronic diseases or their symptoms in older adults.

Literature Review

Overview of the Health Benefits of Strength Training

Research studies over the past 2 decades have produced compelling evidence supporting the feasibility and the benefits of targeted physical activity programs for older adults.[6,10] In particular, the benefits of strength training include increased muscle and bone mass, muscle strength, flexibility, dynamic balance, self-confidence, and self-esteem. Strength training also helps reduce the symptoms of various chronic diseases such as arthritis, depression, type-2 diabetes, osteoporosis, sleep disorders, and heart disease.[11–19] In addition, research demonstrates that strength training in older adults with functional limitations reduces falls.[13,20–22]

Table 1 summarizes several research studies from small, highly controlled interventions with just a few subjects to the more recent larger trials on strength training that are home based. This literature review is not meant to be comprehensive; we have selected several studies to illustrate several important aspects of strength training in older adults. We limited this review to strength-training studies that studied adults aged ≥50 and that did not combine strength-training interventions with a formal aerobic exercise program.

Initial Strength Training Research with Older Adults

Early research investigating the effects of strength training on muscle mass, strength, and function were limited and quite conservative in terms of the intensity of the exercise prescription. As positive results were observed, strength-training protocols for older adults became more progressive and, as a result, more potent in nature. This was demonstrated by the first high-intensity strength-training study in older adults conducted by Frontera et al.[23] at Tufts University in the mid-1980s. Twelve healthy men between the ages of 60 and 72 years strength trained at 80% of their one-repetition maximum (1RM) for knee extension and leg curl. Their prescription—eight repetitions, three sets, 3 days per week—is very similar to many of the protocols being used today in both clinical, community, and home-based settings. They were the first to observe significant increases in muscle mass (≈10%) and strength (≈150%) over the study period of 12 weeks.[23]

Frailty and Falls

The aforementioned study was conducted with healthy, community-dwelling men in their 60s and 70s. The findings from that study initiated novel investigations of the effects of strength training in frail, institutionalized men and women in their 90s by Fiatarone et al.[24] In an effort to examine how strength training could affect muscle weakness and impaired mobility in relation to functional limitations and risk for falls in this population, participants were enrolled in 8 weeks of strength training. In addition to experiencing strength gains of 174% on average and a 9% mid-thigh muscle area, researchers also observed a 48% improvement in tandem gait speed. This combined increase in muscle strength, mass, and walking speed has multiple implications for reducing physiologic and functional impairment as well as decreasing risk for fall and fractures.[24] Fiatarone et al.[25] went on to conduct a similar but larger study in 100 men and women in the same long-term care facility and found similar results.

The study by Campbell et al.[20,21] in New Zealand demonstrated that strength training at home in near frail women (aged ≥80 years) with minimal supervision is possible on a large scale. This study also complemented the strength training with balance training in the home. After 2 years, the women in the exercise group had experienced 31% fewer falls (37% fewer falls resulting in a moderate or severe injury). It is important to note that the women in the exercise group were given instruction during just four home visits; otherwise, the women performed all of the exercise sessions on their own at home.

It is clear that strength training can reduce or delay functional limitations as well as reduce physical impairment and falls. Another critical question within this area of research is strength training's effect on the development and progression of age-related chronic diseases such as depression, arthritis, and type 2 diabetes—all of which can ultimately lead to disability without intervention.

Bone and Joint Health

Several studies have seen improvements in bone density with strength training in older adults.[11,26,27] In one such study, Nelson et al.[11] conducted a longer-term strength-training study in women aged 50 to 70 years. This randomized controlled study was designed to see if 1 year of strength training could reduce the risk of osteoporotic fractures by increasing bone mineral density in estrogen-depleted women. After 1 year of strength training 2 days per week, middle-aged women became stronger, gained muscle mass, improved dynamic balance, and had improvements in bone density

Table 1. Selected review of strength training studies in older adults

Study	Population	Design/duration	Intervention protocol	Setting	Significant outcomes[a]
Frontera et al., 1988[23]	Healthy men aged 60–72 yrs; n=12	Noncontrolled; 12 wks	3 sets; 8 reps/set; 80% of 1RM; knee extensors; knee flexors; 3 × wk	Laboratory based	Strength >100% MTMA 11.4%
Fiatarone et al., 1990[24]	Men and women aged 86–96 yrs; n=10	Noncontrolled; 8 wks	3 sets; 8 reps/set; 80% of 1RM; knee extensors; hip extensors; 3 × wk	Long-term care facility	Strength >150% MTMA 9% Gait speed 48%
Fiatarone et al., 1994[25]	Men and women aged 72–98 yrs; n=100	RCT; 10 wks; four groups: strength training; strength training plus nutrition beverage supplement; nutritional supplement; control group	3 sets; 8 reps/set; 80% of 1RM; knee extensors; hip extensors; 3 × wk	Long-term care facility	Strength 113% Stair-climbing power 28% Gait speed 12%
Nelson et al., 1994[11]	Women aged 50–70 yrs; n=40	RCT; 1 yr: strength training vs control group	3 sets; 8 reps/set; 80% of 1RM; 5 exercises; 2 × wk	Laboratory based	Strength 35%–76% Bone density 1% Balance 14% TBMM 1.2 kg
McCartney et al., 1995[31]	Men and women aged 60–80 yrs; n=142	RCT; 42 wks; strength training vs control group	3 sets; 10–12 reps/set; 80% of 1RM; 7 exercises; 2 × wk	Laboratory based	Strength 20%–65% MTMA 5.5% Treadmill endurance 18%
Skelton et al., 1995[12]	Women aged ≥75 yrs; n=52	RCT; 12 wks; strength training vs control group	3 sets; 4–8 reps/set; progressive; 8 exercises of upper and lower body using body weight, rice bags and elastic tubing	Small-group classes at laboratory 1 × wk + 2 × wk home based	Strength 4%–27% Power 18% No change in functional performance
Singh et al., 1997[16,17]	Men and women aged 60–84 who have depression; n=32	RCT; 10 wks: two groups: strength training and health education	3 sets; 8 reps/set; 80% of 1RM; 5 exercises; 3 × wk	Laboratory based	Strength 33% Depression reduced Sleep improved
Ettinger et al., 1997[28]; Messier et al., 2000[30]	Men and women aged ≥60 yrs; n=439	RCT; 18 months; three groups: aerobic, strength, and health education	Strength training group: ankle weights; 2 sets; 12 reps/set; 9 exercises	Facility-based classes for 3 months followed by 15 months of home-based training	Relative to home education: Pain 8% Physical disability 8% 6-minute walk improved Balance improved NS between aerobic and resistance training group
Campbell et al., 1997[21]; 1999[20]	Women aged ≥80 yrs; n=233	RCT; 2 yrs; with 4 initial home visits; control group received usual care and equal number of home visits	2 sets; 8 reps/set; progressive; 3 × wk; 9 strength exercises (2 bodyweight; 7 with ankle weights); ~9 balance exercises	Home based	NS increase in strength Balance improved Chair-rise improved Falls reduced (relative hazard = 0.69 (0.49—0.97)
Taaffee et al., 1999[34]	Men and women aged 65–79 yrs; n=46	RCT; 24 wks; 1, 2, or 3 days × wk, plus a control group	3 sets; 10 reps/set; 80% of IRM; 8 exercises (days per wk varied depending on group assignment)	Laboratory based	Strength 37%–42% in all 3 exercise groups Chair-rise time in all 3 exercies groups

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Table 1. Selected review of strength training studies in older adults *(continued)*

Study	Population	Design/duration	Intervention protocol	Setting	Significant outcomes[a]
Jette et al., 1999[40]	Men and women ≥60 yrs; with functional limitations; n=215	RCT; 6 months; with 2 home visits; control group was placed on a waiting list for the intervention	35-minute exercise video performing 11 exercises using elastic bands of varying thickness	Home based	Strength 6% to 12% in lower body Tandem gait improved 20% Physical and overall disability 15% to 18%
Baker et al., 2001[15]	Men and women aged 55–82 yrs with osteoarthritis of the knee; n=46	RCT; 16 wks; with periodic home visits; control group received nutrition education program	2 sets; 12 reps/set; progressive; 3 ×wk; 6 exercises (2 functional; 4 with ankle weights)	Home based	Strength 71% Pain 43% Physical function 44% Depression reduced
Thomas et al., 2002[8]	Men and women aged ≥45 yrs with osteoarthritis of the knees (average age 62 yrs); n=786	RCT; 2 yrs; four groups: 30 min/day; multiple lower-body exercises with elastic bands strength training with periodic home visits, strength training with periodic home visits plus telephone contact, telephone contact alone; no intervention	1 set; up to 20 reps; progressive; total exercise time of 20	Home based	Strength improved Pain 12% Physical function improved Knee stiffness reduced
Fielding et al., 2002[37]	Women aged ≥65 yrs (average age 73 yrs); n=30	RCT; 16 wks; high velocity resistance training (HI) vs low-velocity resistance training (LO)	3 sets; 8–10 reps/set; 3 × wk; knee extension and hip extension	Laboratory based	Strength improved similarly in both groups (HI and LO) Power improved significantly more in HI than LO
Castaneda et al., 2002[9]	Hispanic men and women aged 58–82; n=60	RCT; 16 wks; control group received usual care	3 sets; 8 reps/set; 70%–80% 1RM; 5 exercises 3 × wk	Laboratory based	Strength improved HbA1c reduced Abdominal fat Systolic BP Lean tissue
Dunstan et al., 2002[36]	Men and women aged 60–80 yrs with type-2 diabetes; n=36	RCT; 6 months periodic resistance training plus moderate weight loss vs control plus moderate weight loss	3 sets; 8–10 reps/set; 75%–85% 1RM; 9 exercises; 3 × wk	Laboratory based	Strength improved HbA1c reduced Lean tissue Weight loss in both groups
Nelson et al., 2003[32]	Men and women aged 70–92 yrs who scored ≤10 on EPESE at baseline; n=67	RCT; 26 wks; with periodic home visits; control group received nutrition education program	2 sets; 8 reps/set; progressive; 3 × wk; 9 strength exercises (3 bodyweight; 3 ankle weights; 3 dumbbells); 2 balance exercises	Home based	NS increase in strength EPESE 26% Balance 34%

[a]Compared to nonexercising control subjects.
1RM, one repetition maximum; EPESE, Epidemiologic Study of the Elderly summary physical performance score; HbA1c, hemoglobin A1c; MTMA, mid-thigh muscle area; NS, not significant; RCT, randomized-controlled trial; reps, repetitions; TBMM, total body muscle mass.

over and above the control group. In a study by Cussler et al.[27] (which included other modes of exercise in the intervention), there was evidence of a linear relationship between bone mineral density change and total weight lifted over the year, indicating the importance of progression and intensity for improvements in bone.

Laboratory-based interventions such as the study by Ettinger et al.[28–30] have demonstrated beneficial (albeit modest) effects of strength training on reducing the signs and symptoms of osteoarthritis in older adults. In this 18-month trial, 439 adults aged ≥60 who had osteoarthritis of the knee were randomized to three groups: education control, aerobic exercise, or a resistance-training program. Both exercise groups had a 3-month center-based intervention followed by a 15-month home-based intervention. After 18 months, the resistance training group had an 8% lower score on a physical disability questionnaire, 8% lower score on pain, improvements in balance, and walked 57 feet longer on the 6-minute walk than the education control group. There were no differences between the two exercise groups. Interestingly, a cost-effectiveness evaluation demonstrated that the strength-training intervention was more economically efficient than aerobic exercise in improving physical function; however, the magnitude of the difference between the two exercise groups was small.[29]

In 2001, Baker et al.[15] at Tufts University published data regarding strength training in individuals with osteoarthritis. Forty-six community-dwelling individuals aged ≥55 with knee osteoarthritis were randomized to either a home-based strength-training group or an attention control group (nutrition education) for 4 months. Patients in the exercise group experienced significant reductions in pain and improvements in muscular strength, functional performance, physical abilities, quality of life, and self-efficacy. Similarly, Thomas et al.[18] in Nottingham, England, randomized 786 men and women with knee pain to either a self-reported home-based strength-training group (with or without phone contact) or a control group (with or without phone contact). The strength-training group experienced significant reductions in pain and stiffness and improvements in physical function compared to the control group at the 6-, 12-, and 24-month time points. These studies again illustrate that a home-based approach offers a feasible method for implementing strength-training programs in older adults, even in those with functional limitations.[15,18]

Endurance

McCartney et al.[31] completed a 42-week study of strength training in 60- to 80-year-old men and found improvements not only in strength and muscle mass but also in treadmill endurance. A study by Beniamini et al.[14] found similar improvements in treadmill endurance in subjects in a cardiac rehabilitation program when strength training was included in the exercise prescription. These two studies indicate that individuals with low aerobic capacity can realize important improvements in cardiovascular fitness with the inclusion of strength training.

Strength and Functional Performance

At the University of London, scientists studied the effects of 12 weeks of strength training on strength, power, and functional abilities in women aged ≥75.[12] Fifty-two healthy women were randomized to either a 3-day per week strength-training group or a control group, which received no intervention. Two of the three exercise sessions were completed at the study participants' homes while the other session was completed at the research center with supervision. Compared to control subjects, participants in the strength-training group showed significant improvements (27%) in knee extensor muscle strength. Investigators also observed significant improvements in muscular power (18%). They did not observe an effect of the strength-training program on functional tests, possibly because the study subjects were healthy and had no functional limitations at baseline.[12]

However, a recent investigation by Nelson et al.[32] demonstrated significant improvements in physical function following 6 months of home-based strength and balance training in elderly subjects who reported and scored functional impairment prior to entry into the study. Seventy-two independently living men and women aged ≥70 were randomized to either a control group or an exercise group, the latter of which performed strength and balance training three times per week in their own homes. The exercise group experienced a 26% improvement in physical function. These findings highlight the importance of targeted exercise programs for both preventing functional decline and improving physical abilities with age. Furthermore, this study demonstrates that it is possible for near frail elders to strength train at home with minimal supervision and to have meaningful improvements.

Variations Strength Training Prescriptions

There is also the very important question of frequency of training. The current recommendations from the American College of Sports Medicine recommend strength training for musculoskeletal fitness 2 to 3 days per week.[33] The question arises as to whether physiologic improvements can result with just 1 day per week of strength training. Another 6-month intervention examined the effects of 1, 2, or 3 days per week of strength training in 46 community-dwelling elders, compared to a control group.[34] All those participating in strength training experienced significant increases in muscular strength and improvement in chair-stand time compared to the control group, and there was no difference between the three exercise groups. This study demonstrates that as little as 1 day per week of strength training improved strength and physical function. Questions still remain as to whether 1 day a week is enough to improve health outcomes, such as reducing the pain associated with arthritis. Data from this and similar studies are important when considering a safe, effective, and reasonable exercise prescription for healthy older adults in terms of preventing functional limitations and physical impairment.[34]

Emotional Health and Sleep

Several studies have demonstrated that strength training is beneficial to emotional health and vitality, which may be an important factor in preventing disability and early mortality.[35] Singh et al.[16] studied whether strength training alone could reduce the signs and symptoms of depression. After 10 weeks of strength training, men and women who had depression at baseline had reductions in all depression measures as measured by the Geriatric Depression Scale. In addition, quality of sleep improved with the strength training in this group of depressed elders.[17]

Glycemic Control

Research now demonstrates that strength training is also beneficial in improving glycemic control in type-2 diabetics.[19,36] Castaneda et al.[19] randomized older Hispanic men and women, all of whom had type-2 diabetes, to either a strength-training group or a usual-care control group for 16 weeks. After 16 weeks, the strength-training group had reductions in hemoglobin A1c (HbA1c), systolic blood pressure, and abdominal fat along with increases in muscle strength and muscle mass. Improvements in all of these markers greatly reduce type-2 diabetics' risk of future complications and physical impairment related to their diabetes. Similar results were reported by Dunstan et al.[36] in a group of Caucasian men and women.

The Potential of Power Training

As the area of strength-training investigation progresses, some scientists are trying to identify the best models for implementation and dissemination, while others continue their work in determining what exercise prescription will confer the most benefits for older adults. New research from Fielding et al.[37] provides insight into how training for power (defined as the combination of strength and speed) in this population may effectively target functional performance. They randomized 30 women with self-reported disability to either a high-velocity strength-training program or a more traditional low-velocity strength-training program. Subjects completed three lower-body exercises at 70% 1RM three times a week for 16 weeks. Those in the high-velocity strength-training group experienced significantly greater improvements in skeletal muscle power, which, because of the combination of speed and strength, may be an important factor in warding off functional impairment and, therefore, an important consideration in designing exercise programs for older adults.[8]

Key Challenges

Will Strength Training Delay Disability? If So, What Is the Mechanism?

While it seems clear that strength training can have a significant effect on numerous health parameters, research has yet to determine whether it can actually delay the onset of disability in older adults. And, if so, the important question is the mechanism: does the benefit come from improvements in physical parameters such as muscular strength, the preservation of functional abilities, the prevention of chronic diseases, or reduction of burden of disease, or is it via reductions in depression and improvements in self-esteem and self-confidence or the collected contribution of each of these? It could be theorized that strength training helps reduce the risk of developing chronic disease and, therefore, decreases the accompanying symptoms that may impair physical capacity and functional abilities. Another possibility is that, even in the presence of chronic conditions, strength training can help older adults maintain a minimum threshold of strength that is needed to perform functional tasks.

Strength training should be included when designing exercise programs for older adults (with the addition of balance training when indicated for frailer elders). It is important to note that physical and psychological benefits have been clearly demonstrated using strength-training prescriptions that have varied in terms of frequency, intensity, duration, and specific exercises. One area that research must now investigate is whether the addition of strength training to exercise prescriptions for older adults will actually delay the onset of disability in terms of occupation, socialization, and the ability to remain living independently.

What Is the Best Strength-Training Prescription for Different Populations?

Frequency. If, in fact, strength training has the ability—either alone or in conjunction with other modes of exercise—to delay disability, the ideal prescription has yet to be researched and most likely will vary depending upon the target audience. There must be a careful balance between the progression of intensity and the utmost concern for safety and avoidance of injury when working with older adults. It could be argued that three sessions per week is burdensome and, as a result, compliance is likely to be an issue without supervision. Conversely, one session per week, while more conducive to compliance goals, may not confer the maximum health benefits over time. The current American College of Sports Medicine guidelines recommend 2 to 3 days per week of strength training.[33,38] At the present time, this appears to be the best recommendation for strength-training prescription for older adults, as it is manageable from a time perspective, allows for flexibility in scheduling, and will elicit the desired physiologic and psychological benefits described in the above literature review. Further research is needed to determine if 1 day per week of strength training can elicit improvements in health outcomes over time in older adults.

Sets and repetitions. The optimal number of repetitions and sets, as well as the total number of exercises, is another important aspect of exercise programming that is still open for debate. The studies described in the literature review ranged from two different exercises using three sets of eight repetitions to numerous exercises using one set of up to 20 repetitions. Depending on the study population (regarding physiologic capacity or disease burden) there are reasons to prescribe fewer exercises with multiple sets versus eight to ten exercises with only one or two sets. Based on the preponderance of the evidence, it seems prudent to use the following recommendations: when fewer than four exercises are used, prescribe two to three sets; when four to eight different exercises are used, prescribe one to two sets; when greater than eight exercises are used, prescribe one set. The general guidelines of 8 to 15 repetitions recommended by ACSM seem to be prudent advice when working with older adults.[33,38] Finally, future studies may want to examine the design of the exercise program in terms of the variation of its intensity and volume (known as periodization) in studies lasting >12 weeks as well as training for power for older adults as was used by Castaneda et al.[19] and Fielding et al.,[37] respectively.

Intensity. Intensity and progression of the strength-training program may be the biggest challenge in safe and effective exercise prescriptions for older adults. In a laboratory or highly supervised environment, it is feasible to have older adults exercising at a relatively intense workload—most often 70% to 80% of the one-repetition maximum. However, the vast majority of older adults will not be exercising in such a prescriptive, supervised setting. Therefore, strength-training prescription must be as globally applicable as possible.

Two methods for ensuring proper progression and intensity that are currently used when performing 1RMs are an option include the exercise intensity scale and repetition-based progression. In our laboratory at Tufts University we have been successful in using a modified 10-point, Borg exercise-intensity scale for verbally assessing proper intensity.[15,39] A verbal target of 7 to 8 ("hard") on the scale is sufficiently challenging yet not too overwhelming a workload or potentially injurious for older adults. We have begun to combine the use of the intensity scale with a repetition-based method for stimulating progression. It is a fairly simple concept in terms of application and explanation for older adults. For example, if the prescription is two sets of 10 repetitions, the load (or amount of weight being lifted) should be increased when more than 12 repetitions can be completed with proper form.[15] Future studies should examine the options for recommendations regarding intensity as part of a strength-training program. In the end, what is most important is that the individual progresses up to heavier weights over time—always performing the exercises in good form.

Equipment. There is also the question of what equipment is best suited to the needs and abilities of older adults. The primary options are single or multistation machines, body weight, free weights (i.e., dumbbells and adjustable ankle weights), exercise bands, or a combination of all of the above. Probably the most important factor in this instance is access and availability. Where machines are available—as is often true in a clinical or health and fitness centers—there are distinct benefits. In general, achieving the desired intensity level, often times 70% to 80% 1RM, is easier using machines because the mechanics of the equipment allow a larger absolute load to be lifted.

Another important aspect, particularly with this population, is proper body positioning and range of motion for the prescribed exercises. In comparison to free weights, there is less room for misalignment of body positioning when using machines. Having said this, body weight, free weights, and elastic bands have unique advantages for this population, especially in home-based or community settings. They are relatively inexpensive, transportable, and take up minimal space. They may also confer additional benefits in terms of helping older adults maintain or increase kinesthetic awareness as well as dynamic movement and balance.[20,21] It should be noted that current research indicates that body weight exercises and free weights (dumbbells and ankle weights) elicit greater improvements in physiologic capacity (muscle strength and physical function) than elastic bands. Elastic bands are now being tested in larger-scale studies and may be a viable option when free weights are not available.[18,40]

Training environment. The concept of the training environment is an important one, and a question best assessed on an individual basis whenever possible. Current research indicates that meaningful health improvements can be realized from both clinical and home-based strength-training programs. For some older adults, exercising at home is the most realistic and desirable option. No travel is required, and the older adult may feel most at ease. It can also be advantageous in terms of time and scheduling; individuals can exercise whenever they desire, without the constraints of a class schedule, and they can adapt their program as necessary to match their goals. However, for many older adults, the social network and social support of the exercise group enhances program compliance as well as their motivation and enjoyment of strength training. There is also the important benefit of an instructor or peer leader to assist with form, speed of movement, and program adaptations when necessary. Certainly, the greater the physical and cognitive impairment, the greater the need is for close supervision.

Is the Public Health Community Capable of Providing Safe and Effective Strength-Training–Based Programs for Older Adults? If So, Will They Participate?

By far the greatest problem that the public health community faces right now with regards to strength training is increasing the number of safe and effective programs available to older adults within the community. It is our opinion that a concerted effort should be mounted to increase the availability of safe and effective community-based strength-training programs for older adults in urban, suburban, and rural settings. It is well documented for all populations that physical activity is extremely important for health and longevity, yet despite public awareness of the benefits of physical activity and the potential detriments of sedentary lifestyle, the activity level of the U.S. population as a whole is completely insufficient.[1,41] Participation rates become even more dismal when you look at the number of older adults who perform any strength-training exercises on a regular basis. Current data indicate that <10% of the older population participates in regular strength training.[1]

In order to make strength-training programs widely available throughout the country—which will inevitably require financial support from public health agencies, foundations, and the private sector—there must be assurance that the programs will not only be safe and effective, but that they will remain viable over time and that participation rates and corresponding reduced healthcare costs justify their availability.[41] Importantly, individual programs must provide culturally appropriate and specific training options to improve enjoyment of the program and adherence over time. There are a few successful community-based, strength-training programs currently available in several geographic areas in the United States. The Lifetime Fitness Program administered by Group Health in the Pacific Northwest and the Strong Living Program and administered by Tufts University in the Northeast are two such programs that employ a "train the exercise leader" model. While these programs have not undergone scientific evaluation, they provide valuable insight into the interest in such programs; currently the programs have more than 3000 active participants with more individuals on waiting lists ready to enroll. Our experience is that demand for these programs is much greater than available access.

Future Directions for Strength-Training Programs and Older Adults

The effect of strength training on physical and functional status in older adults is a relatively new field of investigation. We are only just beginning to understand the full potential of this mode of exercise in preventing and controlling various disease states and the implications for reducing functional impairments and disability. Many age-related physiologic changes that contribute to sarcopenia occur hormonally, neurologically, metabolically, and behaviorally. Strength training can have a positive impact on each of these physiologic domains and is therefore both a viable and potent adjunct to any physical activity prescription for older adults.

What is not fully understood is the impact of strength training on preventing or delaying the development of disability with age. It is important that in further examining this issue, investigators are discriminating about the assessment tools selected so that both specificity and sensitivity to change are accurately measured and interpreted. Future investigations should also focus attention on identifying the specific mechanisms that catalyze physiologic changes as a result of diverse strength-training interventions. Of equal importance is understanding and mastering effective implementation of strength-training programs in a variety of settings. This will require a dynamic, multifaceted approach involving issues of access, availability, promotion, and safety as well as unique behavioral strategies addressing motivation and barriers to participation.

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References

1. U.S. Department of Health and Human Services. Healthy people 2010: understanding and improving health. Washington DC: U.S. Government Printing Office, 2000.
2. Manton K, Gu X. Changes in the prevalence of chronic disability in the United States black and nonblack population above age 65 from 1982 to 1999. Proc Natl Acad Sci U S A 2001;98:6354–9.
3. Baumgartner R, Koehler K, Gallagher D, et al. Epidemiology of sarcopenia among the elderly in New Mexico. Am J Epidemiol 1998;147:755–63.
4. Janssen I, Heymsfield S, Wang Z, Ross R. Skeletal muscle mass and distribution in 468 men and women aged 18–88 yr. J Appl Physiol 2000;89:81–8.
5. Rosenberg I. Summary comments. Am J Clin Nutr 1989;50:1231–3.
6. Roubenoff R, Hughes V. Sarcopenia: current concepts. J Gerontol 2000; 55:716–24.
7. Roubenoff R. Sarcopenia and its implications for the elderly. Eur J Clin Nutr 2000;54:40–7.
8. Foldvari M, Clark M, Laviolette L, et al. Association of muscle power with functional status in community-dwelling elderly women. J Gerontol 2000; 55:192–9.
9. Chandler J, Duncan P, Kochersberger G, Studenski S. Is lower extremity strength gain associated with improvement in physical performance and disability in frail, community-dwelling elders? Arch Phys Med Rehabil 1998;79:24–30.
10. Chakravarthy M, Joyner M, Booth F. An obligation for primary care physicians to prescribe physical activity to sedentary patients to reduce the risk of chronic health conditions. Mayo Clin Proc 2002;77:165–73.
11. Nelson M, Fiatarone M, Morganti C, Trice I, Greenberg R, Evans W. Effects of high-intensity strength training on multiple risk factors for osteoporotic fractures. JAMA 1994;272:1909–14.

12. Skelton D, Young A, Greig C, Malbut K. Effects of resistance training on strength, power, and selected functional abilities of women aged 75 and older. J Am Geriatr Soc 1995;43:1081–7.
13. Rubenstein L, Josephson K, Trueblood P, et al. Effects of a group exercise program on strength, mobility, and falls among fall-prone elderly men. J Gerontol 2000;55:317–21.
14. Beniamini Y, Rubenstein J, Faigenbaum A, Lichtenstein A, Crim M. High-intensity strength training of patients enrolled in an outpatient cardiac rehabilitation program. J Cardiopulm Rehabil 1999;19:8–17.
15. Baker K, Nelson M, Felson D, Layne J, Sarno R, Roubenoff R. The efficacy of home based progressive strength training in older adults with knee osteoarthritis: a randomized controlled trial. J Rheumatol 2001;28:1655–65.
16. Singh N, Clements K, Fiatarone M. A randomized controlled trial of progressive resistance training in depressed elders. J Gerontol 1997;52:27–35.
17. Singh N, Clements K, Fiatarone M. Sleep, sleep deprivation, and daytime activities: a randomized controlled trial of the effect of exercise on sleep. Sleep 1997;20:95–101.
18. Thomas K, Muir K, Doherty M, Jones A, O'Reilly S, Bassey E. Home based exercise programme for knee pain and knee osteoarthritis: randomised controlled trial. BMJ 2002;325:752.
19. Castaneda C, Layne J, Munoz-Orians L, et al. A randomized control trial of progressive resistance exercise training in older adults with type-2 diabetes. Diabetes Care 2002;25:235–41.
20. Campbell A, Robertson C, Gardner M, Norton R, Buchner D. Falls prevention over 2 years: a randomized controlled trial in women 80 years and older. Age Ageing 1999;28:513–28.
21. Campbell A, Robertson M, Gardner M, Norton R, Tilyard M, Buchner D. Randomized controlled trial of a general practice programme of home based exercise to prevent falls in elderly women. BMJ 1997;315:1065–9.
22. Buchner D, Cress M, de Lateur B, et al. The effect of strength and endurance training on gait, balance, fall risk, and health services use in community-living older adults. J Gerontol 1997;52:218–24.
23. Frontera W, Merideth C, O'Reilly K, Knuttgen H, Evans W. Strength conditioning in older men: skeletal muscle hypertrophy and improved function. J Appl Physiol 1988;64.
24. Fiatarone M, Marks E, Ryan N, Meredith C, Lipsitz L, Evans W. High-intensity strength training in nonagenarians. Effects on skeletal muscle. JAMA 1990;263:3029–34:1038–44.
25. Fiatarone M, O'Neill E, Ryan N, et al. Exercise training and nutritional supplementation for physical frailty in very elderly people. N Engl J Med 1994;330:1769–75.
26. Kohrt W, Ehsani A, Birge S. Effects of exercise involving predominantly either joint-reaction or ground-reaction forces on bone mineral density in older women. J Bone Miner Res 1997;12:1253–61.
27. Cussler E, Lohman T, Going S, et al. Weight lifted in strength training predicts bone change in postmenopausal women. Med Sci Sport Exerc 2003;35:10–7.
28. Ettinger W, Burns R, Messier S, et al. A randomized trial comparing aerobic exercise and resistance exercise with a health education program in older adults with knee osteoarthritis: the Fitness Arthritis and Seniors Trial (FAST). JAMA 1997;277:25–31.
29. Sevick M, Bradham D, Meunder M, et al. Cost-effectiveness of aerobic and resistance training in seniors with knee osteoarthritis. Med Sci Sport Exerc 2000;32:1534–40.
30. Messier S, Royer T, Craven T, O'Toole M, Burns R, Ettinger W. Long-term exercise and its effect on balance in older, osteoarthritic adults: results from the Fitness, Arthritis, and Seniors Trial (FAST). J Am Geriatr Soc 2000;48:131–8.
31. McCartney N, Hicks AL, Martin J, Webber CE. Long-term resistance training in the elderly: effects on dynamic strength, exercise capacity, muscle and bone. J Gerontol 1995;50:97–104.
32. Nelson M, Layne J, Bernstein M, et al. The effects of multi-dimensional home-based exercise on functional performance in the elderly. J Gerontol 2003. In press.
33. American College of Sports Medicine. Position stand: the recommended quantity and quality of exercise for developing and maintaining cardiorespiratory and muscular fitness, and flexibility in healthy adults. Med Sci Sport Exerc 1998;30:975–91.
34. Taaffe D, Duret C, Wheeler S, Robert M. Once-weekly resistance exercise improves muscle strength and neuromuscular performance in older adults. J Am Geriatr Soc 1999;47:1208–14.
35. Penninx B, Guralnik J, Bandeen-Roche K, et al. The protective effect of emotional vitality on adverse health outcomes in disabled older women. J Am Geriatr Soc 2000;48:1359–66.
36. Dunstan D, Daly R, Owen N, et al. High-intensity resistance training improves glycemic control in older patients with type-2 diabetes. Diabetes Care 2002;25:1729–36.
37. Fielding R, LeBrasseur N, Cuoco A, Bean J, Mizer K, Fiatarone Singh M. High-velocity resistance training increases skeletal muscle peak power in older women. J Am Geriatr Soc 2002;50:655–62.
38. American College of Sports Medicine. Position stand: progression models in resistance training for healthy adults. Med Sci Sport Exerc 2002;34:364–80.
39. Borg G, Linderholm H. Perceived exertion and pulse rate during graded exercise in various age groups. Acta Med Scand 1967:194–206.
40. Jette A, Lachman M, Giorgetti M, et al. Exercise—it's never too late: the Strong for Life program. Am J Public Health 1999;89:66–72.
41. U.S. Department of health and Human Services. Physical activity and health: a report of the Surgeon General. Atlanta GA: U.S. Department of Health and Human Services, Centers for Disease Control and Prevention, National Center for Chronic Disease Prevention and Health Promotion, 1996.