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# Musculoskeletal health and the older adult

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**Abstract**—A decline in muscle mass and function, and in the mass and integrity of the skeletal system, are well-known consequences of aging. These changes impinge on the functional performance required for independent living and contribute to frailty and fracture risk. Resistance exercise has been shown to be an effective mode to circumvent age-related changes in the muscular system, although the benefit of exercise on bone mass in the aging skeleton is comparatively modest at best. This brief review highlights results from several studies that we have undertaken in older adults, examining aspects of the resistance training prescription as well as the potential beneficial role of hormones. What is common to all of these studies is the high degree of residual plasticity that remains in aging skeletal muscle. Risk factors for falls and fracture include reduced bone mass, muscle weakness, impaired balance, and lessened visual acuity. Among these, only muscle strength is reliably enhanced with resistance exercise, which may aid in reducing hip fracture risk as well as improving the ability to undertake daily activities and maintain independence.

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## INTRODUCTION

A decrease in bone (1) and muscle mass (2) and an increase in adiposity (3) characterize normal aging. Associated with the decline in muscle mass is a reduction in muscle strength (4) that contributes to frailty, fracture risk, reduction in quality of life, and loss of independence (5). These changes in the musculoskeletal system reflect the aging process *per se*, as well as the consequences of reduced physical activity. In prescribing physical activity and exercise for older adults, opinion articles in the past have emphasized cardiovascular conditioning, with little reference to the undertaking of resistance or strength training (6–8). Although cardiovascular activities such as walking are beneficial to maintaining condition and body weight, and probably do prevent mobility disability, they do not substantially address the decline in musculoskeletal health of the older adult.

The loss of muscle mass with aging, which has been termed sarcopenia (9), along with the associated loss in muscle strength, has a far-reaching biological impact on individuals. This ranges from reduced basal metabolism (10), with its consequent disruption of energy balance (increasing the risk for a number of age-related conditions such as obesity, diabetes, and malnutrition), to reduced mechanical loading of the skeleton, which will negatively affect bone density and strength (11,12). Moreover, everyday tasks, such as rising from a chair and gait performance, are hampered by a reduction in muscle strength (13,14). Consequently, work in our laboratory at the Palo Alto Veterans Affairs Medical Center and elsewhere has been directed at examining the role that exercise may play in preventing the age-related decline in the musculoskeletal system and hence improve the quality of life and functional lifespan for elders. This brief review details the results from several of our exercise trials incorporating resistance training as the exercise mode, as well as pertinent studies from other laboratories. The focus of these studies has centered on components of the exercise prescription as well as pharmacological adjuncts that have been considered likely to augment the response to exercise.

## DISCUSSION

### Foundation Studies in Older Adults

In 1980, Moritani and deVries (15) published the results of their 8-week progressive strength training study of the dominant elbow flexors (3 days per week for 10 repetitions of two-thirds maximal) in five younger and five older men. These showed a similar time course and percentage increase in strength for both age groups, although the neurophysiological mechanism underlying the strength change differed with age. The authors interpreted their results to indicate that, in younger men, neural factors were important in the initial stages of training with subsequent contributions by muscle hypertrophy, whereas in older men there was no evidence for significant hypertrophy. It should be pointed out that muscle biopsies were not taken in that study, so the conclusions were inferential. This and subsequent studies (16) in the early 1980s questioned the potential for gross muscle hypertrophy in older individuals.

However, in 1988, Frontera and colleagues (17) published the results of a resistance training study in 12 men, aged 60–72 years, that generated considerable interest by demonstrating that a high degree of residual plasticity remained in aging skeletal muscle. Following 12 weeks of training, 3 days per week at 80 percent of their one-repetition maximum (1-RM, the maximal amount of weight lifted one time with acceptable form), knee extensor strength increased over 100 percent and knee flexor strength over 200 percent. These dramatic gains in strength were accompanied by an increase in thigh total-muscle cross-sectional area (CSA) of 11.4 percent, as determined by computed tomography, and an increase in the CSA of both Type I (33.5 percent) and Type II (27.6 percent) fibers obtained from vastus lateralis muscle biopsies.

Subsequently, Charette et al. (18) reported a similar study in older women aged 64–86 years, with results comparable to those found in older men. For several muscle groups of the lower body subjected to 12 weeks of moderate- to high-intensity resistance training, strength improved by 28–115 percent, which was accompanied by a 20 percent increase in Type II fiber CSA.

These relatively short-term training studies were followed by exercise trials of 1 year and longer in duration to determine the long-term adaptive response in older men and women. Pyka et al. (19) studied the effects of a year-long resistance training program in elderly men and women that included rapid and sustained increases in muscle strength for upper and lower body muscle groups, accompanied by hypertrophy of both Type I and Type II muscle fibers. Interestingly, the increase in muscle strength was dramatic within the first 3 months, with a lower trajectory of gain thereafter. Type I fiber CSA increased after 15 weeks of training with further hypertrophy apparent by week 30, along with hypertrophy of Type II muscle fibers. As with younger subjects, this study in older adults demonstrated that strength gains derived from training reflect both neural and muscular contributions, the muscle fiber hypertrophy becoming dominant with extended training duration (20). More recently, a 2-year, randomized, controlled weight training trial in older adults demonstrated continued improvements in muscle strength were associated with muscle hypertrophy and functional performance, as indicated by walking and stair-climbing endurance (21).

Of considerable significance to the potential role that exercise may play in preventing frailty and improving the quality of life for the oldest members of society has been the seminal work by Fiatarone and co-workers (22,23) in very elderly nursing home residents. In one study (22), 10 frail volunteers aged 86–96 years underwent 8 weeks of high-intensity resistance training for the knee extensors: three times per week for three sets of eight repetitions. Gains in 1-RM strength (174 percent) and mid-thigh muscle area (9 percent) were accompanied by an improvement in functional mobility. In a subsequent 10-week investigation in a larger cohort of 72–98-year-old residents, similar findings were observed for muscle strength and functional performance, as well as an increased level of spontaneous physical activity (23).

### The Exercise Prescription—Intensity and Frequency

Apart from training mode, the exercise prescription encompasses frequency, intensity, and duration of activity. In general, prescription guidelines for the elderly are based on those devised for young and middle-aged adults, albeit that the pace of training is more gradual and of lower intensity (24). To develop muscle strength and induce an increase in muscle mass, high-intensity resistance exercise—that is, heavy resistance with few repetitions—is advocated, while low-intensity training appears ineffective (25,26). The above-mentioned studies (17–19,21–23) demonstrate the ability of the neuromuscular system of older adults, including the very old, to respond to high-intensity training. However, some studies of older adults also suggest that low-intensity exercise may stimulate modest increases in strength (16,27). It is possible that the strength gains derived from low-intensity exercise result from the relatively detrained state of older adults.

As it has been suggested that moderate gains in muscle strength and aerobic power may prolong independence substantially (13), we examined the effects of high-intensity *versus* low-intensity resistance training, where volume of work was kept constant, over the course of 1 year (28). Women aged 65–79 years undertook thrice weekly exercise, at either 80 percent of their 1-RM for seven repetitions (high intensity) or 40 percent of their 1-RM for 14 repetitions (low intensity). At the end of the trial, both groups experienced significant and similar gains in muscle strength for the knee extensors (60–85 percent) and flexors (65–80 percent) that were associated with Type I and Type II fiber hypertrophy of the vastus lateralis muscle. The ability to achieve substantial and persistent muscle strength gains with fiber hypertrophy using a low-intensity high-repetition training program in older adults has potential applications for those who are apprehensive about their ability to undertake strength training and for those with specific physical limitations.

For exercise programs to be effective, they must meet the needs of older adults. Apart from apprehension about exercise itself, several factors may affect the ability of older individuals to participate, such as access to an exercise facility or time availability. To date, 3 nonconsecutive days per week of training has been frequently employed as a training paradigm in exercise studies (**Table 1**) and the American College of Sports Medicine's 1998 position statement on exercise for healthy adults recommends resistance training a minimum of 2 to 3 days per week (34). However, 3-day/week programs are based on only a few studies in young adults (35,36) and some studies have found improvements in strength when training was performed only once per week (37,38). Moreover, when 3-day/week programs are employed, substantial gains are derived within the first few months with a leveling off of gains thereafter. It may well be that if exercise is performed for a sustained period of time the ultimate strength gain may not appreciably differ with 1, 2, or 3 day per week programs.

**Table 1.**
Characteristics of resistance training prescription components for a sample of studies undertaken with older adults.

| Study | Sets | Reps | Int | Freq | Dur | Sex | Inc |
|---|---|---|---|---|---|---|---|
| Charrette et al. (18) | 3 | 6 | 65-75 | 3 | 12 | F | 69% |
| Pyka et al. (19) | 3 | 8 | 75 | 3 | 52 | M,F | 64% |
| Fiatarone et al. (23) | 3 | 8 | 80 | 3 | 10 | M,F | 113% |
| Nichols et al. (29) | 3 | 8-10 | 80 | 3 | 24 | F | 23% |
| Nelson et al. (30) | 3 | 8 | 80 | 3 | 52 | F | 61% |
| Taaffee et al. (31) | 3 | 8 | 75 | 3 | 24 | M | 34% |
| Lexell et al. (32) | 3 | 6 | 85 | 3 | 11+ | M,F | 106% |
| Sipilä et al. (33) | 3-4 | 8-10 | 70-75 | 3 | 18 | F | 50% |

Reps=repetitions; Int=intensity, in % one repetition maximum (1-RM); Freq=frequency, in days/week; Dur=duration, in weeks; Inc=average 1-RM strength increase, as a percentage dependent on muscle groups evaluated.

Therefore, we investigated frequency of training over a 24-week period in men and women aged 65–79 years (39). Participants were randomized to undertake progressive high-intensity training (80 percent of 1-RM for eight repetitions) for eight upper- and lower-body exercises that targeted the major muscle groups either 1, 2, or 3 days per week. For each exercise, there was no difference among the training groups following 24 weeks with the average gain in strength for each group being approximately 40 percent. Moreover, there was no difference in the time course for improvement in upper- or lower-body muscle groups (**Figure 1**). Gains in muscle strength were accompanied by similar improvements in neuromuscular performance, as indicated by the chair rise test (time to rise from a chair five times without use of the arms) and time to complete a 6-meter backward tandem walk. An increase in lean mass, as assessed by dual energy x-ray absorptiometry (DXA), was noted for the three exercise groups compared to the control group; however, this was modest, indicating a predominant role for nonhypertrophy mechanisms in the development of strength. Since a decline in muscle strength and balance promotes falls and fractures in older adults, a high-intensity training program with a frequency of only once per week may prove useful in reducing the risk for falls and fracture (39).

## Detraining and Retraining

For individuals who exercise, regardless of age, periods of training cessation or relative inactivity may be anticipated. This may be more prevalent in older adults, even those community-dwelling adults in reasonable health, because of illness, hospitalization, and limited periods of disability. The question arises to what degree do older adults retain muscle strength and mass with cessation of activity and how quickly do they recoup these losses with resumption of training? This is of considerable importance, as many of the elderly, especially the very old, live near thresholds of physical ability for activities of daily living (13).

In young resistance-trained adults, a degree of the strength gained with training is lost with cessation of activity, although with short-term detraining (up to 12 weeks) not to pretraining levels (40–42). More importantly, with resumption of training, rapid gains occur in maximal strength (43). The few reports available in older adults suggest that training cessation resulted in a greater loss of strength than in young people (22,44). Therefore, we examined the effects of detraining (12 weeks) and

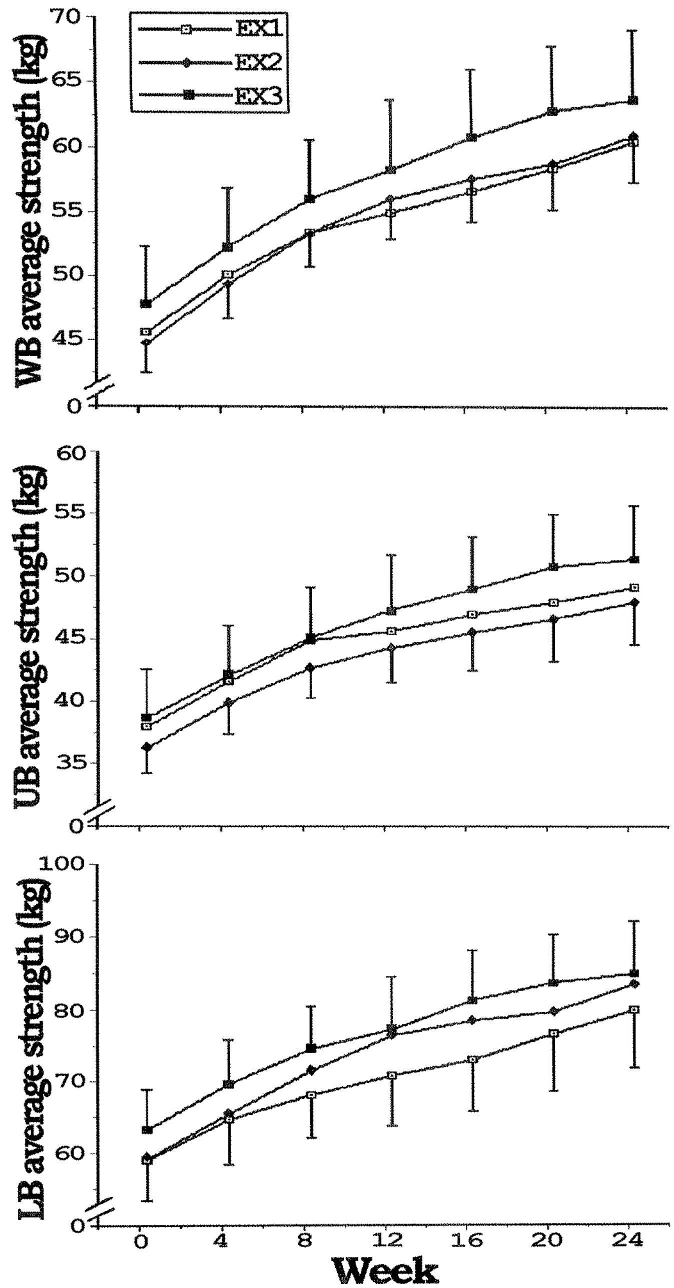


**Figure 1.** The effect of frequency of resistance training on muscle strength gain in older men and women. At no time point for upper (UB) or lower (LB) body strength was there a difference with a training frequency of 1 (EX1), 2 (EX2), or 3 (EX3) days per week. WB refers to whole body muscle strength. (Reprinted with permission from Taaffe DR, Duret C, Wheeler S, Marcus R. Once-weekly resistance exercise improves muscle strength and neuromuscular performance in older adults. J Am Geriatr Soc 1999;47:1208–14.)

resumption of training (8 weeks) on aging muscle in 11 men (65–77 years of age) who had undertaken a strength training program for 24 weeks (45). To monitor the temporal pattern of strength change during these periods, biweekly 1-RM strength assessments for 10 upper and lower body exercises were performed. In addition, needle biopsies for CSA of the major fiber types were obtained from the vastus lateralis muscle.

With the initial 24-week training program, muscle strength increased for all muscle groups of the upper and lower body, ranging from 26 percent for the bench press (upper body, pectoralis major as the prime mover) to 84 percent for the knee extensors. The increased strength was accompanied by significant hypertrophy of Type I (17 percent) and Type II (26 percent) muscle fibers. Somewhat surprisingly, following 12 weeks of detraining, 70 percent of the strength gained with training remained, and the strength that was lost was rapidly recouped within 4–6 weeks of retraining (**Figure 2**). However, with detraining, Type I and Type II fiber CSA reverted to pretraining levels and were only partially restored to the trained values following 8 weeks of retraining. These results again imply a major role for factors other than those related to fiber size, such as enhanced neural drive, motor unit recruitment and synchronization, and skill and learning (20,46) for strength alterations with training, detraining, and retraining.

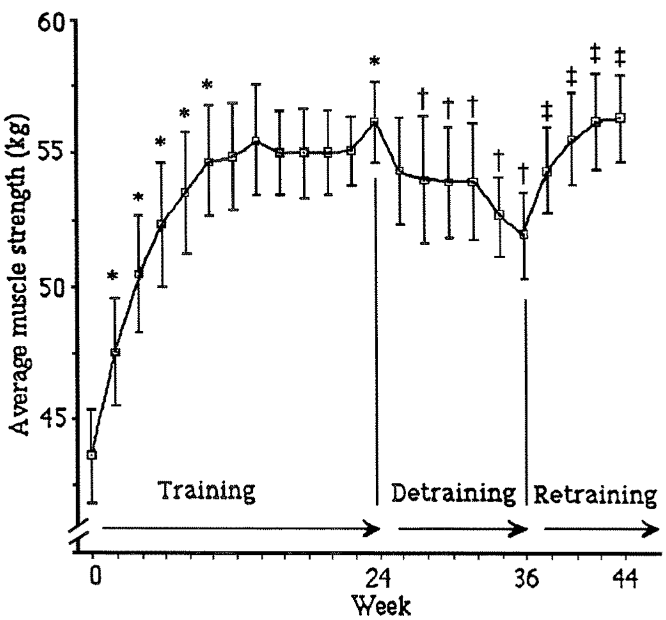


**Figure 2.** Time course for strength change with training, detraining, and retraining in older men. * Significantly different from the preceding strength test during the training phase. †† Significantly different from peak muscle strength. ‡‡ Significantly different from the end of detraining. (Reprinted with permission from Taaffe DR, Marcus R. Dynamic muscle strength alterations to detraining and retraining in elderly men. Clin Physiol 1997;17:311–24.)

As can be seen in **Figure 2**, no change in strength occurred between weeks 2 and 8 of detraining, whereas after week 8 a steep decline in strength was apparent. Similarly, Sforzo et al. (44) found no significant strength change in 9 older resistance-trained adults following 5 weeks of detraining, but following a subsequent 5 weeks all strength gained in the initial 16-week program was lost. Therefore, we cannot discount that, had the detraining period been prolonged to perhaps 24 weeks or more, strength may not have reverted to baseline levels. However, Lexell et al. (32) reported only a minor loss of strength in older men and women (70–77 years) following a prolonged period of detraining with a rapid recouping of lost strength and further gains with resumption of training. In their study, training of the elbow flexors and knee extensors was performed for 11 weeks (with gains in 1-RM of 49 percent and 163 percent, respectively; significant increase in Type I and Type II fiber area for the biceps brachii but not for the vastus lateralis muscle), followed by 27 weeks of detraining and 11 weeks of retraining. The group that detrained for 27 weeks lost only 5 percent of their strength and gained a further 32 percent with retraining. Interestingly, a subgroup that reduced their training frequency from 3 days to 1 day per week during the 27-week detraining period maintained their strength.

It is possible, then, that just the act of measuring strength on multiple occasions during the detraining period dampened the magnitude of strength loss. Similarly, Lexell et al. (32) used four strength measurements during their 27-week detraining period, and it may be that training as infrequently as once every 2 or 4 weeks suffices to largely maintain recently acquired strength in older adults (32,45). This conclusion is supported by studies in younger adults indicating that training once per week (47) or every 2 weeks (42) maintained knee and lumbar extensor strength. This has important ramifications for older individuals who may anticipate a period of inactivity due to immobilization or hospitalization, in that undertaking a program of resistance training before as well as after these periods may speed recovery of functional independence (45). As maintaining independence is a critically important outcome, resistance training may provide a safety margin for performing daily activities following inactivity. In this respect, strength training and physical exercise in general can be viewed as a prehabilitative, as well as rehabilitative, tool in the medical and health care of the elderly.

## Hormones

### *Growth Hormone*

The somatic changes that occur with normal aging are associated temporally with the somatopause, a decline in the activity of the hypothalamic-growth hormone (GH)-insulin-like growth factor-I (IGF-I) axis (48,49). It has been suggested that, as GH deficiency results in similar body compositional changes that are reversed with GH treatment (50), the decreased bone and muscle mass and increased adiposity in aged individuals reflects a state of partial GH deficiency (51). As such, it is tempting to speculate that GH replacement in older adults may restore bone and muscle mass, as well as muscle strength, to that of their former years. Alternatively, agents that stimulate the release of GH and raise circulating levels of IGF-I into the youthful range may be of similar benefit.

Exercise is one method of acutely stimulating the release of GH. However, although resistance exercise elevates circulating GH concentration in healthy young adults in an intensity-dependent fashion, the response in elderly men and women is grossly diminished (52). Moreover, these age-related deficits in circulating GH and IGF-I concentrations at rest or in response to exercise are not repaired following long-term resistance training and the development of a trained state (53). In addition, we have recently reported that oral arginine ingestion in older adults does not stimulate GH secretion to an acute bout of exercise (54). Therefore, apart from using pharmacological agents to stimulate the pituitary release of GH, such as GH-releasing hormone, administration of GH may be the only effective way to restore age-related deficits in the GH/IGF-I axis.

Considerable interest into the potential beneficial effects of GH administration was generated in the gerontology and geriatric fields when Rudman and colleagues (51) published the results of their 6-month trial of GH replacement in men over 60 years of age. Following treatment (3 days/week, given subcutaneously), lean mass increased 8.8 percent, vertebral bone density 1.6 percent, and skin thickness 7.1 percent, and adipose mass decreased by 14.4 percent. We wished to examine if these improvements in body composition were accompanied by altered body function, such as improved muscle strength. Moreover, we wanted to investigate whether the magnitude and time course of strength gain with exercise in elderly individuals are constrained by deficits in somatotrophic function (31).

To address these issues, we performed a randomized, double-blind, placebo-controlled exercise trial (31). Men aged 65–82 years initially underwent 14 weeks of progressive resistance training (3 days per week, three sets of eight repetitions at 75 percent of 1-RM) to invoke a trained state (and not mask a possibly small effect of GH with the rapid strength gains made in the initial stages of training), and were then randomized to receive daily injections of recombinant human GH or placebo while continuing to train for an additional 10 weeks. Although plasma IGF-I concentrations increased to the young adult range, we observed no synergistic effect with resistance exercise on muscle strength at any time point (**Figure 3**). Body composition changes did occur with an increase in lean mass and a decrease in fat mass, especially from the trunk region, in those taking GH (55). As there was no difference in muscle strength between the GH and placebo groups, it is likely that the increased lean mass, measured by DXA, reflected fluid retention as well as

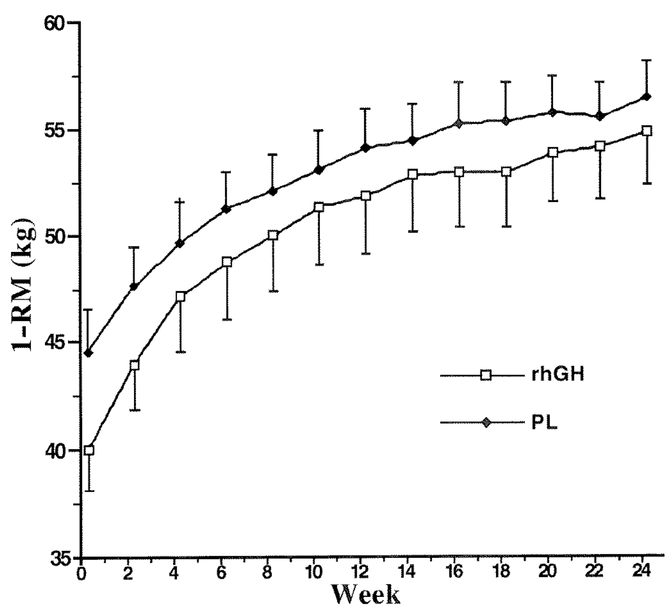


**Figure 3.** Lack of effect of recombinant human growth hormone (rhGH) to augment muscle strength with progressive resistance training. rhGH and placebo (PL) were administered from weeks 14–24. (Reprinted with permission from Taaffe DR, Pruitt L, Reim J, Hintz RL, Butterfield G, Hoffman AR, et al. Effect of recombinant human growth hormone on the muscle strength response to resistance exercise in elderly men. J Clin Endocrinol Metab 1994;79:1361–6.)

increased connective tissue and organ mass (31). Further, GH did not augment the fiber hypertrophy response to exercise (56).

Yarasheski et al. (57) also reported that improvements in muscle growth and strength with heavy-resistance exercise in older men were not augmented when combined with daily GH treatment. Similarly, in postmenopausal obese women, muscle strength was not augmented by GH and/or IGF-I following 12 weeks of exercise (58). These studies lend no support to the use of replacement GH in older adults for improving muscle mass or function. Further, these agents have a nontrivial risk for side effects, including edema, arthralgias and joint stiffness, and carpal tunnel syndrome (31).

*Estrogen and Hormone Replacement Therapy*

In searching for pharmacological agents to maintain or augment muscle mass and strength with aging, anabolic agents such as GH, IGF-I, and testosterone are considered prime candidates. However, in 1993 Phillips and colleagues (59) published the results of a cross-sectional investigation indicating that the decline in specific force (force per CSA) of the adductor pollicis muscle that occurs in women around the time of menopause was preserved in those taking hormone replacement therapy (HRT). Thus HRT, or the use of estrogen alone (ERT), in those who have undergone surgical menopause is associated with conferring protection against bone loss and ischemic heart disease (60,61), as well as relieving vasomotor and genitourinary symptoms associated with menopause (62). The additional protective effect on muscle strength would be important not only in helping to maintain functional independence into old age but also in aiding the prevention of osteoporotic fracture, as muscle strength is related to falls and fracture risk (63,64).

To examine if this protective effect of reproductive hormones was also apparent for large muscle groups of the lower body involved with ambulation, we cross-sectionally assessed muscle strength and areal bone mineral density (BMD) in elderly women taking estrogen and in those with no previous exposure to hormone replacement. As expected, axial and appendicular BMD were greater in individuals receiving estrogen replacement, but there was no difference in lower body muscle strength, even after adjustment for lean mass (65). Similarly, Seeley et al. (66) reported no effect of postmenopausal estrogen use on muscular strength (hip abductors, elbow extensors, and hand grip) or neuromuscular function in a study of osteoporotic fractures that included over 9,000 older women. In a more recent investigation by Greeves et al. (67) involving women undergoing *in vitro* fertilization, maximal strength and fatigue characteristics of the first dorsal interosseus muscle were assessed following downregulation and then during hyperstimulation of the ovaries by gonadotrophin injections. Despite these large fluctuations in estrogen levels, muscle strength and fatigue characteristics were unaltered.

However, two recent prospective trials indicate beneficial effects of HRT on muscle strength. In a randomized 6–12-month trial, maximal voluntary force of the adductor pollicis increased by 12.4 percent in women 5–15 years postmenopausal taking HRT, while nonusers experienced a decline of approximately 3 percent (68). The increase in strength occurred without a related change in muscle CSA. In a longitudinal trial over 39 weeks by Greeves et al. (69), quadriceps and hand-grip strength in early postmenopausal women were preserved in HRT users while those not taking HRT experienced a significant decrease in strength of approximately 10 percent. Therefore, there is cross-sectional and prospective evidence to suggest that reproductive hormones may play a role in preserving as well as augmenting muscle strength in postmenopausal women. The mechanism of such effects remains unclear, although Phillips et al. (59) speculate that it resides at the level of the cross-bridge within the muscle cell. Further, as Greeves et al. (69) point out, it is unclear which of the ovarian hormones is primarily responsible, as HRT preparations contain estrogen and progesterone, or whether it is the interaction of the two, and, if progestin treatment is crucial, whether it is more effective when given in a cyclical or continuous manner. Indeed, it may well be that the androgenic nature of progestins used in European HRT regimens is the active agent.

## Effects of Training on Skeletal Tissue

It is well known that athletes whose skeletons are exposed to increased mechanical loading have increased bone mass and density (for review see 70). The differences between athletes and sedentary counterparts are quite substantial, up to 30 percent or more, which would conform to Wolff's law that bone accommodates the forces applied to it by altering its amount and distribution of mass (71). Although impressive, the results of exercise interventions on BMD in adults is less so, with modest mean changes generally in the order of 1–3 percent reported (72). Without delineating individual studies, three meta-analyses recently published provide an appropriate summary of clinical trials in older adults.

In a meta-analysis examining the effect of aerobic exercise on lumbar spine BMD in postmenopausal women (73), 10 studies that were either randomized or controlled met the inclusion criteria for a total sample consisting of 330 subjects. The individual study duration ranged from 28–80 weeks and activities included walking, low-impact aerobic exercise, jogging, stairclimbing, stationary cycling, and aerobic exercise in water. The results indicated that aerobic exercise helped maintain BMD, while in the nonexercise group BMD declined by 2.5 percent. Kelley (74) also undertook a meta-analysis of randomized trials in postmenopausal women that examined the effect of aerobic and strength training interventions on regional BMD (spine, hip, forearm). Eleven trials were selected that included 719 subjects with an intervention period of 7–24 months. Again, both forms of exercise were beneficial in slowing the rate of bone loss. In a subgroup analysis that excluded the measurement of nonspecific sites and supplement groups, both aerobic and resistance exercise enhanced BMD by 1.62 percent and 0.65 percent, respectively. Similar results were also obtained in a meta-analysis of published controlled trials in pre- and postmenopausal women conducted by Wolff and colleagues (72), who concluded that exercise training could prevent or reverse bone loss at such clinically relevant sites as the femoral neck and lumbar spine. However, the treatment effects were modest at about 1 percent per year for endurance and strength training, although these effects were twice as high when trials were nonrandomized (72).

Although bone mass is an important determinant of bone strength (75), other factors such as bone architecture and quality contribute to the integrity of bone. Animal studies indicate that mechanical characteristics of bone can improve with impact loading without accompanying increases in mineral mass (76). If the mechanical competency of bone also improves, with exercise, in the aging human skeleton despite minimal effects on bone mass, then physical training may directly play an important role in fracture risk reduction. In any event, of the various risk factors for falls and fracture, such as bone mass, muscle weakness, balance, and visual acuity, muscle strength is reliably subject to improvement with training, and strategies aimed at improving muscle function may aid in diminishing hip fracture risk as well as assisting in the prolongation of independence for the older adult.

In summary, muscle strength reliably improves in older adults undertaking resistance exercise, and these gains in strength are accompanied by fiber hypertrophy. Moreover, a training frequency of only one session per week may be sufficient to restore strength and, hence, aid in the performance of daily activities and the maintenance of independence. In comparison, exercise has a modest effect on BMD, although mechanical characteristics of bone may be altered, which would improve bone strength and reduce fracture risk. Therefore, community exercise programs are warranted to improve physical functioning and maximize the length of independence for older adults, which would assist in reducing the financial costs associated with disability and extended nursing home care.

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