Aging Successfully: The Importance of Physical Activity in Maintaining Health and Function

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Abstract

Physicians caring for middle-aged and older patients frequently overlook the importance of regular physical activity. Exercise on a routine basis is an important component of successful aging. It has been shown that many age-related declines in musculoskeletal function can be markedly reduced by participation in some form of regular exercise. Examination of records from masters athletic competitions has been used to determine the true rate of age-related functional declines in highly trained, healthy individuals and further supports these findings. Declines in physical abilities for masters athletes are gradual, which suggests that for many, the potential for participation in competitive athletics can persist well into the seventh decade of life. Recent studies indicate that health gains can be achieved with relatively low volumes of exercise. Indeed, the greatest benefit is seen when one "goes from doing nothing to doing something." Current data suggest that a cumulative total of 30 to 50 minutes of aerobic exercise a day performed 3 to 5 days a week and one set of resistance exercises targeting the major muscle groups twice a week can produce significant health benefits. The aerobic conditioning requirement need not be a formal or structured activity, but can be satisfied through regular participation in many common physical tasks (e.g., walking, gardening, housekeeping). Musculoskeletal injuries are a major cause of noncompliance with any exercise regimen and are especially debilitating for older individuals. Prompt recognition of injury and treatment that emphasizes alternative conditioning exercises and minimizes "downtime" are especially important. Orthopaedists should be aware of the pattern of musculoskeletal injuries seen in this population, so as to assist their patients in avoiding these problems.

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Enhanced longevity coupled with the postwar baby boom has led to record numbers of middle-aged and older individuals in the United States. The US Census Bureau has projected that by the year 2010, more than one half of all Americans will be older than 35 years of age, with 25% being 55 years of age and older.[1] It is widely believed that increasing age brings progressive declines in physical function and loss of independence. Recent evidence has shown, however, that deterioration of physical function and resultant frailty are not an inevitable consequence of aging.

It is important that physicians be aware of the potential benefits of regular physical activity for middle-aged and older adults and that they promote appropriately active lifestyles to these patients. Orthopaedists practicing sports medicine should be as comfortable when prescribing exercise for the promotion of overall health as they are when directing rehabilitation following musculoskeletal injury.

Understanding the age-related changes in musculoskeletal function and being able to differentiate genetically determined manifestations of aging from those resulting from inactivity are critically important. Likewise, knowledge about the benefits of regular exercise and the steps in developing an appropriate exercise program for middle-aged and older adults is necessary for effective counseling of patients. Physicians must also be aware of the patterns of athletic injuries seen in this population and the most efficacious treatment of these injuries when they occur in older individuals.

The Importance of an Active Lifestyle

The US Surgeon General's report on physical activity and health suggests

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that people of all ages, both male and female, can benefit from regular exercise.[2] Exercise has been shown to reduce premature mortality from strokes, coronary artery disease, hypertension, and diabetes mellitus, as well as some forms of cancer.[2] In addition, it has many widely accepted beneficial effects on bones, joints, and muscles. Nevertheless, physical inactivity remains a significant health-care problem in the United States. A recent survey found that fewer than 40% of adults engage in vigorous exercise on a regular basis and that 25% of adults are totally inactive.[2] This pattern of inactivity starts early in life. In a study questioning children about their activities over the previous 2 weeks, only 50% of school-aged children had engaged in activities involving strenuous physical exertion.[2] This trend is also supported by the fact that there was an almost 50% reduction in enrollment in physical education classes in the United States between 1991 and 1995.[2]

An active lifestyle correlates with longevity and is important for both physical and mental well-being. Exercise can greatly retard age-associated declines in basal metabolic rate as well as enhance maximal aerobic capacity in middle-aged and older adults.[3] These adaptations make exercise an important component in combating obesity and its related disorders.

Musculoskeletal benefits of regular exercise include reduction in age-related bone loss, increase in muscle mass, and improvement in muscle strength and neuromuscular coordination. Kirchner et al[4] observed statistically significant higher bone mineral density in former college gymnasts than in female control subjects, suggesting the importance of an active lifestyle for young people who have specific risk factors for the development of osteoporosis. Weight-bearing activities in particular are beneficial for stimulating bone formation in younger persons and for limiting bone resorption in older individuals. Advocating weight-bearing and resistance exercises is especially important for all postmenopausal women.

Functional gains resulting from regular exercise are especially important for the elderly. Light-intensity exercise can reduce the risk of falling.[5] Resistance exercises in particular have been shown to promote improvement in daily function. In one study,[6] walking velocity, stair-climbing power, and spontaneous physical activity in elderly nursing-home dwellers increased in response to a 10-week resistance exercise program. In a symposium on aging and body composition, Evans and Campbell[7] concluded that "there is no pharmacologic intervention that holds a greater promise of improving health and promoting independence in the elderly than does exercise."

Exercise Prerequisites

Participation in a sports or exercise program is predicated on a variety of factors, including motivation, time, and an appropriate venue. The physician can be valuable as a motivator and coach by reinforcing the benefits of regular exercise and by providing guidance in structuring an exercise program. It is helpful to establish a series of realistic goals at the start of any exercise program. Achievement of personal goals is an important predictor of continued athletic activity. Current exercise recommendations demand relatively little time, thereby making a regular exercise program feasible for most people.[8] Masters-level sports leagues exist for those 35 years of age and older and provide the opportunity for age-matched competition in a wide variety of sports. Knowledge about available masters activities can be useful for physicians advocating exercise to their patients. For those not so competitively inclined, it is important to remember that the requirement for aerobic conditioning can be met through regular participation in many routine activities. Participation in household tasks such as cleaning, gardening, and yard work can produce substantial fitness gains for previously inactive individuals.

Although most middle-aged and older adults should be encouraged to participate in some form of exercise, certain exceptions do exist. The American College of Sports Medicine has compiled a list of absolute and relative cardiac contraindications to exercise training[5] (Table 1). Many of these conditions, once properly treated and stabilized, are compatible with some form of modified exercise. Because the prevalence of asymptomatic cardiac disease is higher in middle-aged and older adults, these individuals should be evaluated by their primary-care providers before exercise training is initiated.

Age-Related Musculoskeletal Changes

Aging is associated with a number of predictable functional declines involving the musculoskeletal system. Those declines affecting muscle and tendon function have the greatest impact on functional capacity.[7,9,10] Most age-related changes in muscle can be modified through activity. Muscle weakness in older individuals results from decreased muscle mass (sarcopenia) rather than impairment of the contractile properties of the muscle.[9] For most people, muscle strength peaks at age 30 and begins to decline at age 50. Muscle strength in sedentary individuals declines by approximately 15% per decade between

Table 1
Contraindications to Exercise Training

Absolute
Recent myocardial infarction
Ischemic electrocardiographic changes
Unstable angina
Uncontrolled arrhythmia
Third-degree heart block
Acute congestive heart failure
Relative
Uncontrolled hypertension
Valvular heart disease
Cardiomyopathies
Complex ventricular ectopy
Uncontrolled metabolic disease

the ages of 50 and 70 and by 30% per decade after age 70.[5]

The exact mechanism of age-related muscle loss is still controversial. Muscle atrophy resulting from disuse is characterized by a reduction in the size of muscle fibers, reflecting the loss of actin and myosin. Early studies characterizing age-associated muscle atrophy found reductions in both the size and the number of muscle fibers, with type II fibers being affected to a greater degree than type I fibers.[11] These studies utilized needle biopsies, and the findings may not have been representative of the whole muscle. Lexell and co-workers[12,13] measured individual fiber types and muscle-fiber cross-sectional area in multiple sections of the vastus lateralis muscles from previously healthy male subjects between the ages of 15 and 83. The authors concluded that aging-associated atrophy results primarily from the equal loss of both type I and type II muscle fibers and to a lesser extent from a reduction in the size of individual fibers. However, a statistically significant difference in individual fiber size was present between fiber types. Type II fibers were smaller than type I fibers, making the percentage of the cross-sectional area of the muscle occupied by the type II fibers lower in older subjects.

Age-associated muscle atrophy differs from pure disuse atrophy in that it involves the loss of muscle fibers as well as a reduction in the cross-sectional area of the muscle fibers that remain. Progressive muscle denervation is one possible mechanism underlying age-associated fiber loss. The reduction in the number of spinal motor neurons that has been reported in individuals by the age of 65 likely occurs before that age.[14] The age-related death of lower motor neurons may be the ultimate determinant of the strength gains possible in older adults.

Progressive loss of muscle and tendon flexibility also accompanies the aging process. These changes lead to restriction of joint motion and increased susceptibility to injury. Increased muscle stiffness can occur as a result of an increase in muscle tone (actin-myosin cross-linking) and/or alterations in the extracellular matrix (collagen). Studies examining the effects of reflex inhibition on improvements in muscle flexibility after stretching suggest that changes in the extracellular environment are the primary mediators of muscle and tendon stiffness.[8] Age-related biochemical and biomechanical matrix changes include decreased collagen solubility as a result of increases in tropocollagen cross-linking and decreased tendon flexibility and strength.[15] Maintaining joint flexibility is paramount for optimal functional mobility. It is important to differentiate between the loss of joint motion that can result from diminished soft-tissue flexibility in older individuals and that which results from degenerative joint changes, with accompanying osteophyte formation. The latter is less amenable to stretching exercises.

Exercise Effects

There is substantial evidence to suggest that adoption of an appropriate training regimen by older individuals can decrease the rate of decline of many of the musculoskeletal manifestations of age and inactivity.[5] Maximal oxygen uptake is an indicator of peak cardiac function and muscle oxygen utilization. Maximal oxygen utilization is an accurate indicator of the level of athletic fitness. Heath et al[16] have shown that maximal oxygen utilization declines by 5% to 15% per decade after the age of 25. Age-associated changes in cardiovascular function may account for the greatest portion of this decline.[8] Maintenance of an endurance exercise program throughout life can reduce this rate of decline by 50%.[17] Endurance training has been shown to lead to a 10% to 30% increase in maximal oxygen uptake in individuals up to the age of 70, after which the fitness training effect is lost.[5]

The intensity of training appears to be essential to this effect. Coggan et al[3] measured adaptations of the oxidative capacity of skeletal muscle in response to intense endurance exercises (80% maximal heart rate for 45 minutes a day 4 days a week for 9 to 12 months) in healthy men and women over 60 years of age. Increases in capillary density and in the cross-sectional area of type I and type IIa muscle fibers were observed. These alterations, combined with an increase by as much as 55% in the level of muscle mitochondrial enzymes, led to a 23% increase in maximal O_2 consumption.[3] Endurance training can improve muscle capillarity, glucose transport capacity, and glycogen reserves.[9]

Resistance training is an effective means of retarding many of the declines in muscle function seen with age. Improvements in muscle strength in response to resistance training are possible throughout life. A number of studies have reported two- to threefold increases in upper and lower extremity strength as the result of short-term (10 to 15 weeks) resistance exercise regimens that employ a moderate load.[5] Even greater gains can be achieved with longer periods of strength training.[8] A substantial percentage of exercise-related strength improvement occurs in response to the first repetition with a weight. Subsequent repetitions within the same session present lower stimuli for muscle response.[5,8] Moreover, notable strength gains can occur with as few as two exercise sessions a week.[5,8]

Athletic Performance

Records from masters-level competitions provide insight into the effect of age on peak athletic performance. Age-adjusted records for masters athletes reflect the sum effect of age on the limits of physical performance possible for a specific sport. Participants in these events are in good health and are highly motivated to train; therefore, differences in performance levels between age groups reflect unalterable physiologic processes. Comparisons of track and field–event records are especially helpful in this regard.[18] These activities can be categorized on the basis of the physiologic demand they place on the participant. Events such as the long jump, shot put, and javelin throw require short bursts of powerfully coordinated muscle contraction. They are primarily dependent on anaerobic energy sources and type IIb muscle fiber recruitment. In contrast, middle-distance and longer racing events require submaximal, repetitive rhythmic muscle contractions over longer time periods. The lower strength demands and longer duration of these events place greater emphasis on aerobic metabolic pathways and the function of motor units composed of type I and type IIa muscle fibers.

Masters records for the javelin throw are illustrated in Figure 1. A steady decline in performance for this event occurs after age 35. These records indicate a 20% per decade decline in athletic performance between the ages of 35 and 55. A more rapid decline (by 30%) in record performances occurs between the ages of 55 and 65, and record distances decrease by 36% between the ages of 65 and 75 years. A similar rate of decline in performance is seen in the age-adjusted records for the shot put.[18]

A smaller discrepancy between masters athletes and younger individuals exists for running events.[18,19] Declines of only 10% per decade are present when records for the 100-yard sprint are compared for individuals between the ages of 35 and 65, and it is not until the age of 65 that record times for the 100-yard dash are consistently above 11 seconds.[18] World record times for the 400-meter run remain under 1 minute until early in the seventh decade, with less than a 4% per decade increase in these times occurring up to age 65 (Fig. 2). Review of performance curves for longer-distance races shows a rate of decline approximating 10% per decade between 35 and 65 years of age.[18] On a cellular level, 25% to 30% increases in the concentrations of sarcoplasmic oxidative metabolic enzymes are present when masters athletes and similarly active younger individuals are compared.[20] This appears to be an effective mechanism for compensating for the decline in maximal heart rate that accompanies increasing age.

The Exercise Prescription

Before recommending a specific conditioning program, the physician should identify the existing physical limitations of the individual as well as the goals that he or she is seeking to attain. An exercise program that is acceptable for a middle-aged person seeking to better his tennis game may be inappropriate for someone with more

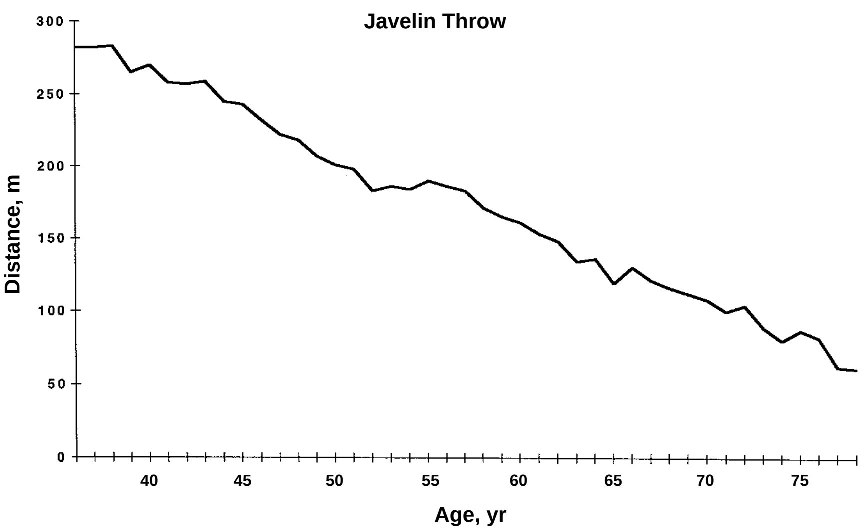

Figure 1 Age-adjusted world-record performances for the javelin throw. (Adapted with permission from Galloway M, Jokl P: Age and sports participation: The effect of aging on muscle function and athletic performance. *Sports Med Arthrosc Rev* 1996;4:221-234.)

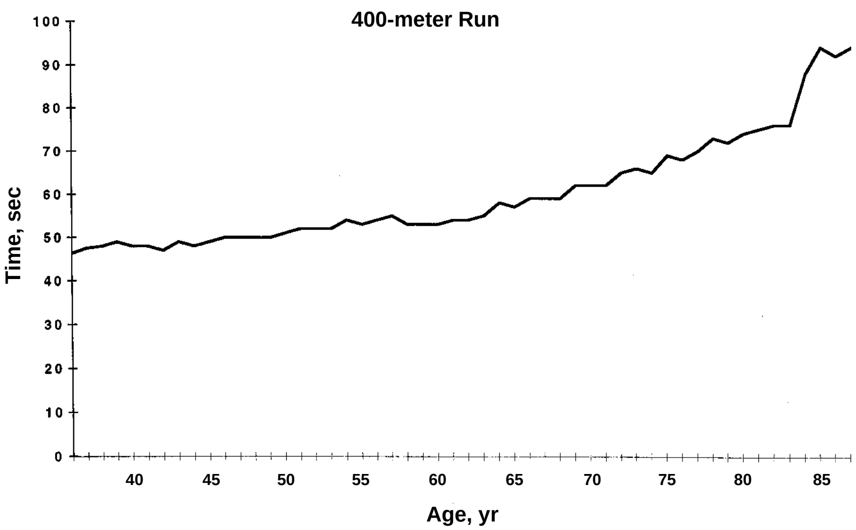

Figure 2 Age-adjusted world-record performances for the men's 400-meter run. (Adapted with permission from Galloway M, Jokl P: Age and sports participation: The effect of aging on muscle function and athletic performance. *Sports Med Arthrosc Rev* 1996;4:221-234.)

specific health needs (e.g., better balance, fewer falls, lower blood pressure, weight loss). Therefore, a needs assessment should be the initial step in the development of an appropriate exercise regimen. This preparticipation inventory includes the goals of the individual and an assessment of the participant's initial physical condition and limitations. It also takes into account the physical demands of the desired activity.

The response to an exercise is proportional to the quantity and intensity of the exercise or activity that is performed. Metabolic fitness refers to a reduction of those risk factors thought to predispose to diabetes and cardiovascular disease. Athletic fitness denotes an increase in maximum oxygen uptake. The quantity (frequency × intensity) of exercise required to achieve an improvement in metabolic fitness is substantially less than that necessary for athletic fitness. Present recommendations for the maintenance of cardiorespiratory fitness in otherwise healthy adults are summarized in Table 2.[8] The goal of these recommendations is the total fitness of the individual and should not be interpreted as being sufficient to prepare for athletic competitions.

Activities suitable for improving cardiorespiratory fitness require the rhythmic activation of the large muscle groups over a time period exceeding the anaerobic energy production capacity of the muscle. Such activities include walking, hiking, running, jogging, aerobic dance, rope skipping, stair climbing, skating, cycling, cross-country skiing, aerobics classes, rowing, swimming, and endurance sports. The workout intensity for endurance training is most easily monitored by targeting a percentage of an individual's maximum heart rate. This technique also has the advantage of correcting for the age of the participant. The recommended intensity for cardiorespiratory conditioning varies from 60% to 90% of an individual's maximum heart rate and depends on the initial level of fitness. The lower target level should be reserved for significantly unfit individuals, as it is less effective than exercise of higher intensity for stimulating the desired physiologic response. Moderate-intensity exercise (80% of maximal heart rate) may be more appropriate for most middle-aged persons. It should be remembered that maximum heart rate loses its value as an indicator of exertion in patients taking β-adrenergic receptor blocking medications. These patients must rely on their breathing and perceived effort to guide their exercise intensity.

Patients seeking improvements in cardiorespiratory conditioning should train for 20 to 60 minutes 3 to 5 days a week. It is important to understand that for fitness, it is not the individual training session that determines the physiologic adaptation, but rather the total volume of training to which the person is exposed throughout the day. Training for 15 minutes three times during the same day carries the same benefit as a single 45-minute training session performed at the same level of intensity. The optimal training frequency is between 3 and 5 days a week. Minimal improvement in the indicators of cardiorespiratory

Table 2
Exercise Quantity for Cardiorespiratory Fitness

Frequency of training:	3-5 days per week
Training intensity:	60%-90% of maximum heart rate
Training duration:	30-60 minutes (continuous or intermittent)

fitness occurs in response to training for less than 2 days a week. However, training more than 5 days a week elicits little additional benefit.

Resistance training has long been overlooked as an equally important component of an exercise regimen. All resistance training regimens involve the principles of overload, specificity, and reversibility. (The concept of muscle overload implies that subjecting the body to a greater stress or load than is usually encountered will elicit the desired physiologic response. Training specificity, as related to resistance-training exercises, denotes the need for similarity between the biomechanical demands of a specific exercise regimen and the functional requirements of the desired sport or activity. Reversibility refers to the need for the continuation of an adequate level of physical stress in order to prevent disuse atrophy.) These factors must be considered when structuring an exercise program. The load magnitude, the number of sets and repetitions, and the interval between training sessions are manipulated to produce the desired cellular response. In addition, the response to a training program is specific to the range of motion through which the joint is moved, as well as to the mode of muscle contraction.

Supervised resistance training is safe and effective for most older persons. Although the risk of cardiac events is increased during exercise, it is far outweighed by the health risks associated with a sedentary lifestyle. In one study,[21] a 30-week resistance program employing three sets of eight repetitions and using 75% of the one-repetition maximum load generated a 50% increase in the cross-sectional area of both type I and type II fibers of older individuals.

Recommendations for strength training are designed to maintain muscle strength, endurance, and fat-free body mass. The minimal effective volume of strength training recommended is one set of 8 to 10 exercises targeting the major muscle groups 2 or 3 days a week. A 2-day-a-week resistance-training regimen elicits 70% to 80% of the strength gains resulting from programs employing more frequent weight-lifting sessions. Most of the strength gains accompanying a resistance training program appear to develop in response to the first set of an exercise.[8] Additional sets result in only small further increases in strength, which may not be important for those undertaking a routine fitness program but is important for those training for participation in competitive sports.

Most healthy adults below the age of 50 should employ a weight that can be lifted for 8 to 12 repetitions. A weight that can be lifted 10 to 15 times is suggested for those 50 years of age and older. It is important that resistance exercises be performed utilizing correct form and technique. The weight should be lifted slowly and rhythmically through the full range of motion of the exercised joint if the maximal benefit is to be realized. Proper breathing techniques are especially important in the older population because marked increases in blood pressure can occur with the Valsalva maneuver during resistance training.

Flexibility exercises should be incorporated into the fitness regimen and should involve the major muscle groups. Regular stretching can restore flexibility in older individuals. Patients should be advised to stretch to the point of slight discomfort; however, pain should be avoided. Stretches are best performed after a period of warm-up and should be held for 10 to 30 seconds. At least four repetitions of a stretch should be performed for each muscle group 2 to 3 days a week.[5] Muscle contraction and relaxation prior to passive stretching may enhance the degree of stretch obtained.

Avoiding Injury

Injury is a major concern for physically active older individuals. Activity-related musculoskeletal injury is one of the most common barriers to exercise for this population. Several risk factors for activity-related injuries have been identified.[21,22] These include previous joint injuries, obesity, osteoarthritis, joint deformity, weakness, and restricted joint motion.

Although there is no conclusive evidence that the incidence of injury is higher in older age groups, it does appear that the time required for return to activity after injury is greater for older individuals. In a survey of masters athletes, Kavanagh and Shephard[23] demonstrated that more than 60% of these athletes missed at least 1 week of activity after a sports-related injury, and one third remained out of their sport for over a month. Kallinen and Alen[24] reported persistence of symptoms with resulting athletic disability for more than 1 year in 20% of patients over the age of 70 with activity-related injuries. These observations point to the importance of injury prevention, prompt recognition, and appropriate treatment of injuries in older athletes.

Total inactivity during recuperation from musculoskeletal injury should be avoided to maximize the chance that the patient will return to the previous activities. It is especially important to emphasize alternative training. The use of pool therapy (water running, water aerobics) is especially helpful for these patients.

Matheson et al[25] compared the pattern of sports-related injury seen in patients under and over the age of 50. Overuse was the cause in

85% of cases. The knee was a common site of involvement in both age groups. While tendinitis and muscle strains were the most common diagnoses in both age groups, metatarsalgia, Morton's neuroma, plantar fasciitis, osteoarthritis, degenerative disk disease, and meniscal tears were present three times more often among the older athletes. More than 80% of all the injuries resolved uneventfully, with surgery being required for fewer than 5% of patients.

Training errors are a common cause of overuse injury. They are especially frequent in the older athlete who is beginning a new activity. The risk of overuse injury is related to the total volume of activity to which a person is exposed and the adaptive potential of the region. Patients, especially those with osteoarthritis involving the lower extremity, should be counseled to avoid hard surfaces and high-impact activities. The use of insoles composed of shock-absorbing materials can be helpful. Degenerative joint disease is frequently compatible with a modified program of exercise. In one study,[25] preexisting osteoarthritis was found to be responsible for activity-related pain in only one third of older patients. This suggests that care should be taken in attributing activity-related symptoms to osteoarthritis and therefore limiting a patient's participation in athletics or exercise, when the pain may in fact arise from a treatable soft-tissue disorder.

Given the predilection for overuse injury to the foot, older athletes should be advised with regard to proper footwear and surface conditions. Shoes should possess a resilient shock-absorbing sole, a wide toe-box, and sufficient arch support. The addition of an antipronation orthotic or viscoelastic insert can be helpful for selected patients. To prevent knee injury, quadriceps-strengthening exercises should be instituted, and older patients should be cautioned to avoid high-impact activities as well as those requiring high degrees of knee flexion or torsional forces.

Overuse injuries can be reduced by slowly advancing both the duration and the intensity of the new activities, as well as through the incorporation of cross-training into the weekly exercise regimen. The risk for muscle strain injury can be reduced by the incorporation of a period of warm-up and stretching before sports participation. It has been shown that warming a muscle results in greater force generation and increased elongation prior to failure. Both of these properties would be expected to be protective against eccentric strain injury by increasing the force-absorbing potential of the muscle. Middle-aged and older patients should be advised about the importance of calf-stretching exercises before participation in activities requiring running or jumping. Proper patient education and conditioning can substantially reduce the incidence of injury in older athletes.

Summary

An active lifestyle is important for the preservation of health and function in aging individuals and should be encouraged by physicians caring for older patients. Many of the declines in musculoskeletal function traditionally attributed to aging can be reduced through regular exercise. Review of records from masters athletic competitions revealed surprisingly high levels of performance. Indeed, it has been shown that a positive response to exercise can be obtained at any age. A needs analysis assessing the physical deficits and exercise limitations of the individual is the first step in constructing an exercise prescription. As is the case with training for a specific sport, exercise programs for older individuals should be tailored to the specific needs of the patient and should be designed to offset age- and inactivity-related musculoskeletal changes while minimizing the risk of injury.

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