EXERCISE IN THE OLDER ADULT: FROM THE SEDENTARY ELDERLY TO THE MASTERS ATHLETE

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Abstract: The diverse exercise goals of the aging population present several challenges to physicians. Whereas some Masters athletes aim to set personal time records, sedentary elderly persons may look to exercise to help maintain independence and combat functional decline. This review article examines the common cardiovascular and neuromuscular physiological changes associated with aging and how regular exercise is used to improve physiological parameters and functional abilities. Exercise precautions specific to the elderly population are discussed. Exercise recommendations for persons with osteoarthritis and after joint arthroplasty also are presented.

INTRODUCTION

The definition of the term “elderly” varies depending on the physical requirements placed on an individual. Among sedentary persons, individuals ages 65-75 years are considered the young old, whereas persons ages 75-85 years are considered the middle old and those older than 85 years are considered the very old [1]. Adults aged 50-64 years with functionally limiting chronic medical conditions likely will benefit from the same recommendations as those appropriate for older individuals [2].

Even greater diversity exists among Masters athletes, where age-based stratification begins at age 18 years for swimmers, age 35 years for track and field competitors, and age 50 years for golfers. World Masters Athletics has international events and standards for age grading that take into account the natural physiologic changes that occur with aging and allow masters runners to compare their performance with younger competitors. Masters athletes may be newcomers to sport and exercise or may have had prominent, competitive careers since adolescence. The Masters athlete, therefore, is competing not only against others but often also against the prior performance capabilities of his or her younger self. In endurance sports, older athletes compete against the clock, and expectations about time performance often must be restructured. In team sports, these athletes are faced with younger and younger opponents and may need to employ different strategies to remain competitive. The Masters athlete continues a regular and structured training regimen, often with the goal of improving performance and exercise capacity. Part of the exercise prescription and routine evaluation of these individuals should include not only education regarding the natural physiology of aging and the benefits of continued activity, but also how best to refine their competition goals without diminishing their competitive spirit.

Compared with Masters athletes, even basic activities of daily living can exceed the functional capacity of a sedentary elderly individual. The spectrum of function with normal aging challenges the patient and physician alike, requiring the clinician to periodically re-evaluate goals and expectations and assist the patient in maximizing both functional independence and quality of life. With close attention to the functional losses and physiologic changes of aging, it may be possible to address these changes through individually tailored exercise programs to specifically target areas of need.

PHYSIOLOGICAL CHANGES OF AGING

Physical endurance directly correlates with the ability to transport and metabolize oxygen during exertional activity. A peak aerobic power (VO\text{2}\text{max}) of 15-20 mL/kg per min is...
necessary to support independent community living; seden-
tary individuals often reach this milestone by age 80-85 years
[1,3,4]. A natural decline in peak oxygen transport occurs
that accelerates after age 50 years, when losses can average
0.4-0.5 mL/kg per minute per year, equivalent to 5%-10%
per decade [5,6]. Much of this decline has been attributed to
progressive inactivity, changes in body fat composition, and
peripheral and cardiac muscle deconditioning [7]. A meta-
analysis concluded that a healthy but sedentary 67-year-old
person could expect to improve his or her VO2max by approxi-
imately 3.8 mL/kg per minute after 4-5 months of moderate
intensity exercises performed 3 times per week [4]. Given
that VO2max fluctuations of 5 mL/kg per minute roughly
correlate with a 10-year change in biologic age [1], attention
to potentially modifiable risk factors through such an inter-
vention may sustain a person’s ability to live independently in
the community.

Even for healthy persons, progressive impairments in
cardiovascular function affect activity tolerance [1]. Aging
individuals experience a steady decline in maximal heart rate,
impaired compliance with diastolic filling, incomplete empty-
ting in systole, and reduced inotropic response to sympa-
thetic input, all of which negatively affect stroke volume,
ejection fraction, and cardiac output [5]. Although these
changes are unlikely to affect an elderly person at rest, activity
or exercise-induced tachycardia can exacerbate any mechan-
ical disadvantages of the heart. Impaired diastolic function
can predispose an individual to the development of further
cardiac comorbidities, such as atrial fibrillation, ischemia,
and heart failure [8], with additional implications for physi-
cal activity.

Sarcopenia, which is characterized by losses in muscle
mass, strength, and endurance, also contributes to the func-
tional consequences of aging because of changes in muscle
fibers, protein synthesis, and mitochondrial function. Even
in healthy persons, muscle strength and power begins to
decline around age 25 years, particularly in the lower extremi-
ties [9]. The process accelerates after age 65 years, when a
 typical person already has lost 25% of his or her peak youth
strength [1,10]. By age 80 years, up to 50% of peak skeletal
muscle mass can be lost, likely related more to loss of actual
muscle fibers rather than fiber atrophy [10].

These changes disproportionately contribute to deficits
in total strength, strength per unit of cross-sectional muscle
area, power, and fatigue [11], and can lead to func-
tional decline. Age-related decreases in androgens and
other growth factors may contribute to this process with
selective loss of type II (fast twitch) muscle fibers, less syn-
chronization of motor units, and deteriorating muscle quality
and myosin function [12,13]. The functional consequences
of age-related muscle fiber loss can be tempered through
regular physical activity, because active individuals exhibit
more favorable trajectories of muscle atrophy and potentially
can recover losses accumulated during periods of relative
inactivity [11,14,15].

EXERCISE PRESCRIPTION

The exercise prescription for elderly patients does not differ
significantly from the prescription for younger adults. It is
recommended that adults participate in a minimum of 150
minutes of moderate intensity or 60 minutes of vigorous
physical activity per week. Older adults with functionally
limiting chronic diseases should be as active as their medical
condition allows in order to reduce sedentary behavior [2].
Intensity is measured by perceived exertion rather than met-
abolic equivalents of the task to take into account varying
levels of fitness in elderly persons [2]. Elderly patients have
longer recovery periods and require longer warm-up and
cool-down periods. The mantra of no more than a 10%
increase in volume or intensity is vital for older athletes,
because fatigue plays a larger role as we age [16].

Traditional resistance training recommendations for older
adults consists of 10-15 repetitions of 8-10 exercises that
train major muscle groups at moderate to high intensity at
least twice per week [2]. Older adults should also participate
in flexibility exercises for at least 10 minutes twice a week
with 10-30 seconds per static stretch and 3-4 repetitions for
each exercise [2]. Balance activities should be performed at
least twice per week for older persons at risk of falls. Balance
training should be progressed by gradually reducing the base
of support, adding dynamic movements to perturb the center
of gravity, stressing postural muscle groups, and reducing
sensory input [6].

When choosing the type of exercise program to prescribe,
it may be that a staged prescriptive approach is better, first
targeting the urgent needs of the patient, and then including
other modalities. This approach is particularly evident in
sedentary elderly persons who may benefit from balance
training acutely after a series of falls before the addition of
resistance or aerobic training [17].

BENEFITS OF EXERCISE

A significant decrease in cardiovascular and all-cause mortal-
ity occurs with increased activity. Regular physical activity
not only helps reduce the risk of many conditions associated
with aging, including cardiovascular disease, diabetes, and
stroke, but it also is recommended as treatment for many of
these same conditions [5,18,19]. The greatest benefit is seen
between sedentary adults and normally active adults, indicat-
ing that even a small increase in physical activity can produce
large gains. A combination of resistance and aerobic training
seems to be more effective than either alone [5].

Weakness and functional deficits that accumulate with
aging are predictors of age-related morbidity and loss of
autonomy [20]. Improvements in strength can lead to de-
creased physical disability with a delay in onset of functional decline [21], helping the elderly to remain independent. Regular physical activity also can improve mood and psychological health and has been shown to be effective for treatment of depression [5,22].

Resistance training increases muscle mass, helping to combat age-related sarcopenia [20,23]. In fact, disuse may be the underlying reason for muscle atrophy and weakness, rather than simply aging [24,25]. High velocity training improves power (the ability to generate force rapidly), which is disproportionately decreased in the elderly, and may be more associated with functional abilities and fall risk than muscle strength alone [5,26].

Aerobic exercise training can increase maximal aerobic capacity to help reduce age-related decline. It also leads to decreased stiffness of large elastic arteries, an independent risk factor for cardiovascular disease in older adults [5,27]. Endurance athletes have lower levels of large elastic artery stiffness, enhanced vascular endothelial function, less arterial wall hypertrophy, and lower blood pressure than do sedentary adults. Even 3 months of regular brisk walking has been shown to improve carotid artery compliance [28,29].

**Balance**

Balance is affected by accumulating factors that occur with age, including postural hypotension, as well as impaired proprioception, vision, and other sensory losses. Older adults also demonstrate larger postural sway, slower gait velocity, and decreased ability to recover from perturbation with slower correcting reflexes. Slow walking speeds have been associated with an increased risk of fractures, hospital admissions, institutionalization, and death. Up to 30%-60% of community dwelling older adults fall each year, and 5%-10% of these falls result in serious injury [30]. An increased number of medications also is associated with an increased risk of falls [31,32].

Even simple walking is an effective intervention to improve locomotor function, as measured by such tests as the 6-minute walk and timed get up and go. The addition of low intensity/high velocity strength training is helpful in frail older adults, but healthy adults may require a more varied program, with the addition of aerobic exercise, flexibility exercise, and balance training to improve functional outcomes [33]. Frail or institutionalized persons may have an increased risk of falls when initiating a physical activity regime and require proper supervision [31].

Traditional balance programs include only voluntarily controlled exercises, whereas newer balance training methods increase training specificity by adding more perturbation or multitask activities, such as cognitive and motor tasks. Perturbation training improves compensatory strategies for recovery of balance and equilibrium [34]. Although this training improves balance, it is not yet proven that it can reduce fall risk when performed alone.

The addition of power strength training to balance training also can be useful. Elderly persons often lose not only strength but also the ability to generate force rapidly, making it more difficult to regain balance after a stumble or trip. Multimodal exercise programs that include balance training have been shown to reduce falls and injuries from falls [5]. Some evidence also exists that practicing tai chi can reduce the risk of falls and fear of falling, although gains may not be seen in the frail elderly population [21,35].

**Bone Density**

A history of weight-bearing activity as an adolescent or young adult is not sufficient to prevent against osteopenia/osteoporosis, and continued weight-bearing or resistive exercise is needed to counteract age-related decreases in bone mineral density (BMD) [36]. BMD is an important risk factor for fractures in elderly patients, and it begins to decline after peaking in the third decade [37,38]. The typical loss of 0.5% per year seen after age 40 years is even more exaggerated in postmenopausal women, who accumulate deficits of 2%-3% per year [5,39].

Bone loss is most rapid during the early postmenopausal years [40], which likely explains why exercise implemented within the first 10 years of menopause has a larger effect size on BMD than if it is started later [36]. A simple walking program may not be enough to increase BMD in previously sedentary adults [41], but it may prevent age-related decline in BMD and may lower fracture risk [5]. The addition of resistance exercises or higher impact training may be more beneficial [41,42]. It may be that the improvement in BMD is not as important as the decrease in fall risk seen with exercise that ultimately leads to a decreased risk of fracture [43], although this theory remains to be proven.

**Cognition**

Regular physical activity is linked to a decreased risk of dementia and cognitive decline [44] and leads to improved cognitive performance in older adults, especially for executive functioning [5]. Regular exercise has been shown to improve cognitive function [45] and is associated with a decreased risk of mortality [46] in patients with dementia. Walking and light exercise also can decrease wandering, aggression, and agitation in patients with dementia [47]. Combined physical activity with caregiver training may improve physical functioning, decrease depression scores, and delay institutionalization in patients with Alzheimer disease [48].

**PREPARTICIPATION EVALUATION**

Elderly patients are at an increased risk of injury compared with their younger counterparts. From the Masters athlete to
The sedentary elderly person about to begin a walking program, all can benefit from a dedicated preparticipation evaluation.

Older athletes may be at higher risk of chronic overuse injuries. Collagen fibers begin forming cross bridges in early adulthood, affecting elasticity of connective tissues and joint flexibility [5]. This decreased elasticity of tendons, combined with decreased tensile strength, can lead to increased risk of tendinopathy. An increased risk of degenerative meniscal tears, rotator cuff injuries, tendon rupture (particularly of the Achilles and quadriceps), and rotator cuff injuries also exists [49]. A complete musculoskeletal examination before beginning an exercise program may help to identify areas that are at increased risk, whether from decreased available range of motion, muscle imbalances, altered muscle firing patterns, or other biomechanical deficits that could benefit from a targeted rehabilitation approach.

Coronary artery disease is the most common cause of sudden cardiac death in athletes older than 40 years [50,51]. Unaccustomed vigorous activity is more likely to result in acute myocardial infarction or sudden cardiac death than is less-intense activity [52]. A thorough history and physical examination is the first step in preparticipation screening. Specifics for cardiovascular screening in Masters athletes before they initiate or resume an exercise program are outlined in Table 1 [50,51].

<table>
<thead>
<tr>
<th>Age (y)</th>
<th>Cardiovascular Risk</th>
<th>Recommended Test</th>
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<tbody>
<tr>
<td>&gt;40</td>
<td>Low</td>
<td>ECG</td>
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<tr>
<td>&gt;40 M, &gt;50 F</td>
<td>Moderate to high*</td>
<td>Stress test</td>
</tr>
<tr>
<td>&gt;65</td>
<td>Low</td>
<td>Stress test</td>
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<tr>
<td>Any Symptoms of CAD</td>
<td>Stress test</td>
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<tr>
<td>Any Documented CAD</td>
<td>Echocardiography</td>
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<tr>
<td>Any Inducible ischemia</td>
<td>Echocardiography</td>
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EGC = electrocardiogram; M = male; F = female; CAD = coronary artery disease.

*Moderate to high risk = age plus one or more of the following: dyslipidemia, hypertension, current or recent smoker, diabetes, or a history of myocardial infarction or sudden cardiac death in a first-degree relative <60 years old.

Exercise precautions

Certain medical conditions are more prevalent in the elderly, which, when combined with the physiological changes that accompany aging, can lead to increased risks associated with exercising in this population. Physicians should educate their patients about these risks appropriately so that exercise may be undertaken safely.

Persons with diabetes should monitor blood sugars more closely both during and after physical activity and should recognize that insulin requirements may decrease. Medical alert identification is helpful in times of emergency. Persons with peripheral neuropathy should wear proper footwear and perhaps should avoid heavy weight-bearing activity. Patients with retinopathy should avoid rapid increases in blood pressure, such as with weight lifting or sprinting, that may precipitate retinal hemorrhage or detachment [5].

Many common medications that are more commonly used in the elderly population can have negative effects on performance in active persons. Elderly persons also are more likely to be taking multiple medications, which can lead to increasing adverse effects. Statin-induced myalgias may be more apparent in athletes than in sedentary individuals [50]. β-Blockers can impair performance in persons engaging in high-intensity competitive sports [51]. Vasodilators, such as calcium channel blockers, nitrates, and α-blockers, can decrease cardiac output and may cause hypotension if exercise is stopped abruptly [53]. Longer cool-down periods are recommended for athletes taking these medications [5].

Elderly athletes also must pay special attention to fluid intake to prevent dehydration and overheating [18]. In elderly persons, the thirst mechanism is less sensitive and increased excretion of water from the kidneys occurs, which places elderly athletes at increased risk of dehydration. Hydration status can affect the toxicity of medications, including nonsteroidal anti-inflammatory drugs, and recovery from dehydration also takes longer [16,54]. Diuretics and drugs that lower peripheral vascular resistance may cause increased susceptibility to the effects of dehydration and lead to dizziness and hypotension [53].

Exercising in extremes of temperature also requires special consideration. The elderly are less able to maintain body temperature when exposed to cold. They also display impaired cutaneous vasodilation and decreased sweating abilities in heat, although the latter may be more related to aerobic capacity than to chronological age [55].

Certain nutritional requirements also change with age. Elderly persons experience a decline in the resting metabolic rate, accompanied by a decline in energy expenditure and lean body mass, that results in a lower amount of calories necessary to maintain body weight [18]. Exercise can help to combat these changes and allow the active older person to consume more calories without associated weight gain.
Elderly persons may need increased amounts of protein compared with younger counterparts, but in general, carbohydrate and fat requirements are unchanged [16]. A decreased ability to synthesize vitamin D and to absorb calcium and food-bound vitamin B12 leads to increased daily intake requirements of these micronutrients [16]. In addition, low vitamin D levels may be independently correlated with increased fall risk [56]. Supplementation is recommended for all older adults at risk of falls, and when combined with calcium, may reduce the risk of fractures [31].

EXERCISE IN PERSONS WITH OSTEOARTHRITIS

Aging-related changes to joints include cellular changes within the extracellular matrix that lead to loss of cartilage thickness, proteolysis, glycation, and abnormal calcium deposition [57], which may predispose a joint to developing osteoarthritis (OA). Both animal studies and retrospective human studies offer conflicting evidence about the risk of developing OA with high-impact physical activity. A recent review [58] concluded that not enough evidence exists to draw an unequivocal conclusion but that moderate running does not seem to increase the risk of knee OA and may even have a protective effect. A history of joint trauma is a greater risk factor for development of OA than sports participation. Higher intensity and duration of sport or underlying joint instability may increase the risk of developing OA [58,59].

Patients with OA of weight-bearing joints tend to self-limit activities in an effort to decrease pain. A great deal of individual variation exists over time, with some patients experiencing improvement and some experiencing deterioration. The presence of a higher morbidity count, increased pain, avoidance of activity, and decreased range of motion all have been associated with limitations of activities and functional decline [60,61]. A lack of regular self-reported physical activity almost doubles the odds of functional decline and limitations in daily tasks in persons with OA [61].

Both global and segmental strengthening have a favorable effect on pain and function in sedentary patients with OA [59]. Even simple education and performance of a walking protocol [62] or aquatic therapy [63] can help improve function and decrease symptom severity.

Exercise After Total Joint Replacement/Total Joint Arthroplasty

Patients increasingly are choosing joint replacements not just for pain relief but also to allow them to resume activity and sports participation. Unfortunately, athletic activities lead to increased forces across the prosthetic joint, with increased surface wear, stress at the bone-implant surface, and a higher risk of traumatic injury to the joint [64].

Before any return to activity after an arthroplasty, the patient first must have adequate strength, balance, and coordination [49]. In general, activities performed for regular exercise should be low impact, but higher impacts may be acceptable for occasional recreational activities performed less frequently [64,65]. Risks of higher activity levels include instability, fracture, early loosening, and premature revision, but these risks must be balanced with the multiple health benefits of exercise [66]. Some evidence exists that patients are more likely to return to high levels of activity after hip as opposed to knee replacements, which may be the result of higher levels of residual pain after knee arthroplasty [67].

Studies that compare the survival rates of joint replacements between active and nonactive patients generally are retrospective with limited length of follow-up. It follows, then, that recommendations of allowed sports are generally expert opinion. Updated surveys of the Hip Society, the Knee Society, and the American Association of Hip and Knee Surgeons reveal an increasing number of allowable activities for patients after total joint arthroplasty [66,68]. Recommendations for selected sports are presented in Table 2 [66,68].

 Certain sports such as hiking and running, which place high loads on the knee in flexion, may be better tolerated after total hip arthroplasty rather than total knee arthroplasty [64]. A right-handed golfer will place more torque on the left knee, which may increase pain and lead to decreased performance and length of drives [66]. To decrease pain and wear on the knee, hikers should use poles and find routes that are less steep when descending hills. Skiers should avoid moguls, steep slopes, and hard snow if possible. Cyclists should increase their saddle height and use a lower gear with higher cadence to decrease loads across the knee [64].

SUMMARY

Understanding the biologic changes that occur with age and their social implications is essential for a practitioner working to maximize an aging patient’s quality of life and functional independence. With appropriate guidance and a personally tailored exercise program based on a patient’s fitness goals and functional abilities, as well as medical and orthopedic comorbidities, persons of all levels can achieve improvements in performance and general well being.
REFERENCES


