



**AMERICAN COLLEGE
of SPORTS MEDICINE®**

POSITION STAND

Exercise and Physical Activity for Older Adults

This pronouncement was written for the American College of Sports Medicine by Wojtek J. Chodzko-Zajko, Ph.D., FACSM, (Co-Chair); David N. Proctor, Ph.D., FACSM, (Co-Chair); Maria A. Fiatarone Singh, M.D.; Christopher T. Minson, Ph.D., FACSM; Claudio R. Nigg, Ph.D.; George J. Salem, Ph.D., FACSM; and James S. Skinner, Ph.D., FACSM.

SUMMARY

The purpose of this Position Stand is to provide an overview of issues critical to understanding the importance of exercise and physical activity in older adult populations. The Position Stand is divided into three sections: Section 1 briefly reviews the structural and functional changes that characterize normal human aging, Section 2 considers the extent to which exercise and physical activity can influence the aging process, and Section 3 summarizes the benefits of both long-term exercise and physical activity and shorter-duration exercise programs on health and functional capacity. Although no amount of physical activity can stop the biological aging process, there is evidence that regular exercise can minimize the physiological effects of an otherwise sedentary lifestyle and increase active life expectancy by limiting the development and progression of chronic disease and disabling conditions. There is also emerging evidence for significant psychological and cognitive benefits accruing from regular exercise participation by older adults. Ideally, exercise prescription for older adults should include aerobic exercise, muscle strengthening exercises, and flexibility exercises. The evidence reviewed in this Position Stand is generally consistent with prior American College of Sports Medicine statements on the types and amounts of physical activity recommended for older adults as well as the recently published *2008 Physical Activity Guidelines for Americans*. All older adults should engage in regular physical activity and avoid an inactive lifestyle.

In the decade since the publication of the first edition of the American College of Sports Medicine (ACSM) Position Stand “Exercise and Physical Activity for Older Adults,” a significant amount of new evidence has accumulated regarding the benefits of regular exercise and physical activity for older adults. In addition to new evidence regarding the importance of exercise and physical activity for healthy older adults, there is now a growing body of knowledge supporting the prescription of exercise and physical activity for older adults with chronic diseases and disabilities. In 2007, ACSM, in conjunction with the American Heart Association (AHA), published physical activity and public health recommendations for older adults

(see Table 1 for a summary of these recommendations) (167). Furthermore, the College has now developed best practice guidelines with respect to exercise program structure, behavioral recommendations, and risk management strategies for exercise in older adult populations (46). Recently, the Department of Health and Human Services published for the first time national physical activity guidelines. The *2008 Physical Activity Guidelines for Americans* (50) affirms that regular physical activity reduces the risk of many adverse health outcomes. The guidelines state that all adults should avoid inactivity, that some physical activity is better than none, and that adults who participate in any amount of physical activity gain some health benefits. However, the guidelines emphasize that for most health outcomes, additional benefits occur as the amount of physical activity increases through higher intensity, greater frequency, and/or longer duration. The guidelines stress that if older adults cannot do 150 min of moderate-intensity aerobic activity per week because of chronic conditions, they should be as physically active as their abilities and conditions allow.

This revision of the ACSM Position Stand “Exercise and Physical Activity for Older Adults” updates and expands the earlier Position Stand and provides an overview of issues critical to exercise and physical activity in older adults. The Position Stand is divided into three sections: Section 1 briefly reviews some of the structural and functional changes that characterize normal human aging. Section 2 considers the extent to which exercise and/or physical activity can influence the aging process through its impact on physiological function and through its impact on the development and progression of chronic disease and disabling conditions. Section 3 summarizes the benefits of both long-term exercise and physical activity and shorter-duration exercise programs on health and functional capacity. The benefits are summarized primarily for the two exercise modalities for which the most data are available: 1) aerobic exercise and 2) resistance exercise. However, information about the known benefits of balance and flexibility exercise is included whenever sufficient data exist. This section concludes with a discussion of the benefits of exercise and physical activity for psychological health and well-being.

0195-9131/09/4107-1510/0
MEDICINE & SCIENCE IN SPORTS & EXERCISE®
Copyright © 2009 by the American College of Sports Medicine
DOI: 10.1249/MSS.0b013e3181a0c95c

TABLE 1. Summary of ACSM/AHA physical activity recommendations for older adults.

The current consensus recommendations of the ACSM and AHA with respect to the frequency, intensity, and duration of exercise and physical activity for older adults are summarized below. The ACSM/AHA Physical Activity Recommendations are generally consistent with the 2008 DHHS Physical Activity Guidelines for Americans, which also recommend 150 min-wk⁻¹ of physical activity for health benefits. However, the DHHS Guidelines note that additional benefits occur as the amount of physical activity increases through higher intensity, greater frequency, and/or longer duration. The DHHS Physical Activity Guidelines stress that if older adults cannot do 150 min of moderate-intensity aerobic activity-wk⁻¹ because of chronic conditions, they should be as physically active as their abilities and conditions allow.

Endurance exercise for older adults:

Frequency: For moderate-intensity activities, accumulate at least 30 or up to 60 (for greater benefit) min-d⁻¹ in bouts of at least 10 min each to total 150–300 min-wk⁻¹, at least 20–30 min-d⁻¹ or more of vigorous-intensity activities to total 75–150 min-wk⁻¹, an equivalent combination of moderate and vigorous activity.

Intensity: On a scale of 0 to 10 for level of physical exertion, 5 to 6 for moderate-intensity and 7 to 8 for vigorous intensity.

Duration: For moderate-intensity activities, accumulate at least 30 min-d⁻¹ in bouts of at least 10 min each or at least 20 min-d⁻¹ of continuous activity for vigorous-intensity activities.

Type: Any modality that does not impose excessive orthopedic stress; walking is the most common type of activity. Aquatic exercise and stationary cycle exercise may be advantageous for those with limited tolerance for weight bearing activity.

Resistance exercise for older adults:

Frequency: At least 2 d-wk⁻¹.

Intensity: Between moderate- (5–6) and vigorous- (7–8) intensity on a scale of 0 to 10.

Type: Progressive weight training program or weight bearing calisthenics (8–10 exercises involving the major muscle groups of 8–12 repetitions each), stair climbing, and other strengthening activities that use the major muscle groups.

Flexibility exercise for older adults:

Frequency: At least 2 d-wk⁻¹.

Intensity: Moderate (5–6) intensity on a scale of 0 to 10.

Type: Any activities that maintain or increase flexibility using sustained stretches for each major muscle group and static rather than ballistic movements.

Balance exercise for frequent fallers or individuals with mobility problems:

ACSM/AHA Guidelines currently recommend balance exercise for individuals who are frequent fallers or for individuals with mobility problems. Because of a lack of adequate research evidence, there are currently no specific recommendations regarding specific frequency, intensity, or type of balance exercises for older adults. However, the ACSM Exercise Prescription Guidelines recommend using activities that include the following: 1) progressively difficult postures that gradually reduce the base of support (e.g., two-legged stand, semitandem stand, tandem stand, one-legged stand), 2) dynamic movements that perturb the center of gravity (e.g., tandem walk, circle turns), 3) stressing postural muscle groups (e.g., heel stands, toe stands), or 4) reducing sensory input (e.g., standing with eyes closed).

The ACSM/AHA Guidelines recommend the following special considerations when prescribing exercise and physical activity for older adults. The intensity and duration of physical activity should be low at the outset for older adults who are highly deconditioned, functionally limited, or have chronic conditions that affect their ability to perform physical tasks. The progression of activities should be individual and tailored to tolerance and preference; a conservative approach may be necessary for the most deconditioned and physically limited older adults. Muscle strengthening activities and/or balance training may need to precede aerobic training activities among very frail individuals. Older adults should exceed the recommended minimum amounts of physical activity if they desire to improve their fitness. If chronic conditions preclude activity at the recommended minimum amount, older adults should perform physical activities as tolerated so as to avoid being sedentary.

Definition of terms. Throughout the review, the Institute of Medicine’s definitions of physical activity and exercise and related concepts are adopted, where *physical activity* refers to body movement that is produced by the contraction of skeletal muscles and that increases energy expenditure. *Exercise* refers to planned, structured, and repetitive movement to improve or maintain one or more components of physical fitness. Throughout the Position Stand, evidence about the impact of exercise training is considered for several dimensions of exercise: *aerobic exercise training* (AET) refers to exercises in which the body’s large muscles move in a rhythmic manner for sustained periods; *resistance exercise training* (RET) is exercise that causes muscles to work or hold against an applied force or weight; *flexibility* exercise refers to activities designed to preserve or extend range of motion (ROM) around a joint; and *balance* training refers to a combination of activities designed to increase lower body strength and reduce the likelihood of falling. Participation in exercise and the accumulation of physical activity have been shown to result in improvements in *Physical fitness*, which is operationally defined as a state of well-being with a low risk of premature health problems and energy to participate in a variety of physical activities. *Sedentary living* is defined as a way of living or lifestyle that requires minimal physical activity and that encourages inactivity through limited choices, disincentives, and/or structural or financial barriers. There is no consensus in the aging literature regarding when *old age* begins and no specific guidelines about the *minimum age* of participants in studies that examine the

various aspects of the aging process. The recently published ACSM/AHA physical activity and public health recommendations (167) for older adults suggest that, in most cases, “old age” guidelines apply to individuals aged 65 yr or older, but they can also be relevant for adults aged 50–64 yr with clinically significant chronic conditions or functional limitations that affect movement ability, fitness, or physical activity. Consistent with this logic, in the present review, most literatures cited are from studies of individuals aged 65 yr and older; however, occasionally, studies of younger persons are included when appropriate.

Process. In 2005, the writing group was convened by the American College of Sports Medicine and charged with updating the existing ACSM Position Stand on exercise for older adults. The panel members had expertise in public health, behavioral science, epidemiology, exercise science, medicine, and gerontology. The panel initially reviewed the existing ACSM Position Stand and developed an outline for the revised statement. Panel members next wrote background papers addressing components of the proposed Position Stand, using their judgment to develop a strategy for locating and analyzing relevant evidence. The panelists relied as appropriate on both original publications and earlier reviews of evidence, without repeating them. Because of the breadth and diversity of topics covered in the Position Stand and the ACSM requirement that Position Stands be no longer than 30 pages and include no more than 300 citations, the panel was not able to undertake a systematic review of all of the published evidence of the benefits of physical activity in the older population. Rather, the

Position Stand presents a critical and informed synthesis of the major published work relevant to exercise and physical activity for older adults.

Strength of evidence. In accordance with ACSM Position Stand guidelines, throughout this Position Stand, we have attempted to summarize the strength of the available scientific evidence underlying the relationships observed in the various subsections of the review. An Agency for Health Care Research and Quality (AHRQ) report notes that no single approach is ideally suited for assessing the strength of scientific evidence particularly in cases where evidence is drawn from a variety of methodologies (260). The AHRQ report notes that significant challenges arise when evaluating the strength of evidence in a body of knowledge comprising of combinations of observational and randomized clinical trial (RCT) data as frequently occurs in aging research. The AHRQ consensus report notes that although many experts would agree that RCTs help to ameliorate problems related to selection bias, others note that epidemiological studies with larger aggregate samples or with samples that examine diverse participants in a variety of settings can also enhance the strength of scientific evidence. Consistent with this approach, in this Position Stand, the writing group adopted a taxonomy in which both RCT and observational data were considered important when rating the strength of available evidence into one of four levels. In each case, the writing group collectively evaluated the strength of the published evidence in accordance with the following criteria:

1. *Evidence Level A.* Overwhelming evidence from RCTs and/or observational studies, which provides a consistent pattern of findings on the basis of substantial data.
2. *Evidence Level B.* Strong evidence from a combination of RCT and/or observational studies but with some studies showing results that are inconsistent with the overall conclusion.
3. *Evidence Level C.* Generally positive or suggestive evidence from a smaller number of observational studies and/or uncontrolled or nonrandomized trials.
4. *Evidence Level D.* Panel consensus judgment that the strength of the evidence is insufficient to place it in categories A through C.

SECTION 1: NORMAL HUMAN AGING

Structural and functional decline. With advancing age, structural and functional deterioration occurs in most physiological systems, even in the absence of discernable disease (152). These age-related physiological changes affect a broad range of tissues, organ systems, and functions, which, cumulatively, can impact activities of daily living (ADL) and the preservation of physical independence in older adults. Declines in maximal aerobic capacity ($\dot{V}O_{2max}$) and skeletal muscle performance with advancing age are two examples of physiological aging (98). Variation in each of these measures are important determinants of exercise

tolerance (245) and functional abilities (16,41) among older adults. Baseline values in middle-aged women and men predict future risks of disability (19,192), chronic disease (18) and death (18,160). Age-related reductions in $\dot{V}O_{2max}$ and strength also suggest that at any submaximal exercise load, older adults are often required to exert a higher percentage of their maximal capacity (and effort) when compared with younger persons.

Changing body composition is another hallmark of the physiological aging process, which has profound effects on health and physical function among older adults. Specific examples include the gradual accumulation of body fat and its redistribution to central and visceral depots during middle age and the loss of muscle (sarcopenia) during middle and old age, with the attendant metabolic (113,190) and cardiovascular (123,222) disease risks. A summary of these and other examples of physiological aging, the usual time course of these changes, and the potential functional and clinical significance of these changes are provided in Table 2.

Evidence statement and recommendation. *Evidence category A.* Advancing age is associated with physiologic changes that result in reductions in functional capacity and altered body composition.

Declining physical activity. Older populations are generally less physically active than young adults, as indicated by self-report and interview, body motion sensors, and more direct approaches for determining daily caloric expenditure (53,216,261). Although the total time spent per day in exercise and lifestyle physical activities by some active older adults may approach that of younger normally active adults (11,217), the types of physical activities most popular among older adults are consistently of lower intensity (walking, gardening, golf, low-impact aerobic activities) (191,209) compared with those of younger adults (running, higher-impact aerobic activities) (209). A detailed breakdown of physical activity participation data by age groups and physical activity types is beyond the scope of this review; however, the National Center for Health Statistics maintains a database of the most recent monitoring data for tracking Healthy People 2010 objectives including physical activity. Data are included for all the objectives and subgroups identified in the Healthy People 2010, including older adults (166).

Evidence statement and recommendation. *Evidence category A/B.* Advancing age is associated with declines in physical activity volume and intensity.

Increased chronic disease risk. The relative risk of developing and ultimately dying from many chronic diseases including cardiovascular disease, type 2 diabetes, obesity, and certain cancers increases with advancing age (137,217,222). Older populations also exhibit the highest prevalence of degenerative musculoskeletal conditions such as osteoporosis, arthritis, and sarcopenia (176,179,217). Thus, age is considered a primary risk factor for the development and progression of most chronic degenerative disease states. However, regular physical activity substantially modifies these risks. This is suggested by studies demonstrating a

TABLE 2. Summary of typical changes in physiological function and body composition with advancing age in healthy humans.

Variables	Typical Changes	Functional Significance ^a
Muscular function		
Muscle strength and power	Isometric, concentric, and eccentric strength decline from age ~40 yr, accelerate after age 65–70 yr. Lower body strength declines at a faster rate than upper body strength. Power declines at faster rate than strength.	Deficits in strength and power predict disability in old age and mortality risk.
Muscle endurance and fatigability	Endurance declines. Maintenance of force at a given relative intensity may increase with age. Age effects on mechanisms of fatigue are unclear and task-dependent.	Unclear but may impact recovery from repetitive daily tasks.
Balance and mobility	Sensory, motor, and cognitive changes alter biomechanics (sit, stand, locomotion). These changes + environmental constraints can adversely affect balance and mobility.	Impaired balance increases fear of falling and can reduce daily activity.
Motor performance and control	Reaction time increases. Speed of simple and repetitive movements slows. Altered control of precision movements. Complex tasks affected more than simple tasks.	Impacts many IADL and increases risk of injury and task learning time.
Flexibility and joint ROM	Declines are significant for hip (20%–30%), spine (20%–30%), and ankle (30%–40%) flexion by age 70 yr, especially in women. Muscle and tendon elasticity decreases.	Poor flexibility may increase risks of injury, falling, and back pain.
Cardiovascular function		
Cardiac function	Max HR ($208 - 0.7 \times \text{age}$), stroke volume, and cardiac output decline. Slowed HR response at exercise onset. Altered diastolic filling pattern (rest, ex). Reduced left ventricular ejection fraction %. Decreased HR variability.	Major determinant of reduced exercise capacity with aging.
Vascular function	Aorta and its major branches stiffen. Vasodilator capacity and endothelium-dependent dilation of most peripheral arteries (brachial, cutaneous) decrease.	Arterial stiffening and endothelial dysfunction increase CVD risk.
Blood pressure	BP at rest (especially systolic) increases. BP during submaximal and maximal exercise are higher in old vs young, especially in older women.	Increased systolic BP reflects increased work of the heart
Regional blood flow	Leg blood flow is generally reduced at rest, submaximal, and maximal exercise. Renal and splanchnic vasoconstriction during submaximal exercise may be reduced with age.	May influence exercise, ADL, and BP regulation in old age
O ₂ extraction	Systemic: same at rest and during submaximal exercise, same or slightly lower at maximal exercise. Legs: no change at rest or during submaximal exercise; decreased slightly at maximal exercise.	Capacity for peripheral O ₂ extraction is relatively maintained.
Blood volume and composition	Reduced total and plasma volumes; small reduction in hemoglobin concentration.	May contribute to reduced max stroke volume via reduced cardiac preload.
Body fluid regulation	Thirst sensation decreases. Renal sodium- and water-conserving capacities are impaired. Total body water declines with age.	May predispose to dehydration and impaired exercise tolerance in the heat.
Pulmonary function		
Ventilation	Chest wall stiffens. Expiratory muscle strength decreases. Older adults adopt different breathing strategy during exercise. Work of breathing increases.	Pulmonary aging not limiting to exercise capacity, except in athlete.
Gas exchange	Loss of alveoli and increased size of remaining alveoli; reduces surface area for O ₂ and CO ₂ exchange in the lungs.	Arterial blood gases usually well-maintained up to maximal exercise.
Physical functional capacities		
Maximal O ₂ uptake	Overall decline averages $0.4\text{--}0.5 \text{ mL}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}\cdot\text{yr}^{-1}$ (9% per decade) in healthy sedentary adults. Longitudinal data suggest rate of decline accelerates with advancing age.	Indicates functional reserve; disease and mortality risk factor.
O ₂ uptake kinetics	Systemic O ₂ uptake kinetics at exercise onset is slowed in old vs young, but this may be task specific. Prior warm-up exercise may normalize age difference.	Slow $\dot{V}O_2$ kinetics may increase O ₂ deficit and promote early fatigue.
Lactate and ventilatory thresholds	Ventilatory thresholds (expressed as a percentage of $\dot{V}O_{2\text{max}}$) increase with age. Maximal lactate production, tolerance, and clearance rate postexercise decline.	Indicative of reduced capacity for high intensity exercise.
Submaximal work efficiency	Metabolic cost of walking at a given speed is increased. Work efficiency (cycling) is preserved, but O ₂ debt may increase in sedentary adults.	Implications for caloric cost and $\dot{V}O_2$ prediction in older adults.
Walking kinematics	Preferred walking speed is slower. Stride length is shorter; double-limb support duration is longer. Increased gait variability. These age differences are exaggerated when balance is perturbed.	Implications for physical function and risk of falling.
Stair climbing ability	Maximal step height is reduced, reflects integrated measure of leg strength, coordinated muscle activation, and dynamic balance.	Implications for mobility and physically demanding ADL.
Body composition/metabolism		
Height	Height declines approximately 1 cm per decade during the 40s and 50s, accelerated after age 60 yr (women > men). Vertebral disks compress; thoracic curve becomes more pronounced.	Vertebral changes can impair mobility and other daily tasks.
Weight	Weight steadily increases during the 30s, 40s, and 50s, stabilizes until ~age 70 yr, then declines. Age-related changes in weight and BMI can mask fat gain/muscle loss.	Large, rapid loss of weight in old age can indicate disease process.
FFM	FFM declines 2%–3% per decade from 30 to 70 yr of age. Losses of total body protein and potassium likely reflect the loss of metabolically active tissue (i.e., muscle).	FFM seems to be an important physiological regulator.
Muscle mass and size	Total muscle mass declines from age ~40 yr, accelerated after age 65–70 yr (legs lose muscle faster). Limb muscles exhibit reductions in fiber number and size (Type II > I).	Loss of muscle mass, Type II fiber size = reduced muscle speed/power.
MQ	Lipid and collagen content increase. Type I MHC content increases, type II MHC decreases. Peak-specific force declines. Oxidative capacity per kg muscle declines.	Changes may be related to insulin resistance and muscle weakness.
Regional adiposity	Body fat increases during the 30s, 40s, and 50s, with a preferential accumulation in the visceral (intra-abdominal) region, especially in men. After age 70 yr, fat (all sites) decreases.	Accumulation of visceral fat is linked to CV and metabolic disease.
Bone density	Bone mass peaks in the mid to late 20s. BMD declines $0.5\%\cdot\text{yr}^{-1}$ or more after age 40 yr. Women have disproportionate loss of bone ($2\%\text{--}3\%\cdot\text{yr}^{-1}$) after menopause.	Osteopenia (1–2.5 SD below young controls) elevates fracture risk.
Metabolic changes	RMR (absolute and per kg FFM), muscle protein synthesis rates (mitochondria and MHC), and fat oxidation (during submaximal exercise) all decline with advancing age.	These may influence substrate utilization during exercise.

Typical changes generally reflect age-associated differences on the basis of cross-sectional data, which can underestimate changes followed longitudinally.

^a The strength of existing evidence for the functional associations identified in the far right column ranges between A and D.

BMI, body mass index; BP, blood pressure; CVD, cardiovascular disease; IADL, instrumental ADL; MHC, myosin heavy chain; Peak, peak or maximal exercise responses; RMR, resting metabolic rate.

statistically significant decrease in the relative risk of cardiovascular and all-cause mortality among persons who are classified as highly fit (and/or highly active) compared with those in a similar age range who are classified as moderately fit (and/or normally active) or low fit (and/or sedentary). The largest increment in mortality benefit is seen when comparing sedentary adults with those in the next highest physical activity level (19). Additional evidence suggests that muscular strength and power also predict all-cause and cardiovascular mortality, independent of cardiovascular fitness (69,122). Thus, avoidance of a sedentary lifestyle by engaging in at least some daily physical activity is a prudent recommendation for reducing the risk of developing chronic diseases and postponing premature mortality at any age. Although a detailed breakdown of the impact of physical activity on the reduction in risk of developing and dying from chronic diseases is beyond the scope of this review, the recently published *Physical Activity Guidelines Advisory Committee Report* (51) by the Department of Health and Human Services (DHHS) provides a comprehensive summary of the evidence linking physical activity with the risk of developing and dying from a variety of different conditions. The report contains information for the general population as well as for older adults in particular.

Evidence statement and recommendation. *Evidence category B.* Advancing age is associated with increased risk for chronic diseases, but physical activity significantly reduces this risk.

SECTION 2: PHYSICAL ACTIVITY AND THE AGING PROCESS

Physical activity and the aging process. Aging is a complex process involving many factors that interact with one another, including primary aging processes, “secondary aging” effects (resulting from chronic disease and lifestyle behaviors), and genetic factors (152,258). The impact of physical activity on primary aging processes is difficult to study in humans because cellular aging processes and disease mechanisms are highly intertwined (137). There are currently no lifestyle interventions, including exercise, which have been shown to reliably extend maximal lifespan in humans (98,175). Rather, regular physical activity increases average life expectancy through its influence on chronic disease development (via reduction of secondary aging effects). Physical activity also limits the impact of secondary aging through restoration of functional capacity in previously sedentary older adults. AET and RET programs can increase aerobic capacity and muscle strength, respectively, by 20%–30% or more in older adults (101,139).

Evidence statement and recommendation. *Evidence category A.* Regular physical activity increases average life expectancy through its influence on chronic disease development, through the mitigation of age-related biological changes and their associated effects on health and well-being, and through the preservation of functional capacity.

Factors influencing functional decline in aging.

Although the pattern of age-related change for most physiological variables is one of decline, some individuals show little or no change for a given variable, whereas others show some improvement with age (119). There are also individuals for whom physical functioning oscillates, exhibiting variable rates of change over time (120,187,192), possibly reflecting variable levels of physical activity and other cyclical (seasonal) or less predictable (sickness, injuries) influences. However, even after accounting for the effect of different levels of physical activity, there is still substantial between-subject variability (at a given point in time and in rates of change over time) for most physiological measures, and this variability seems to increase with age (231). Individual variation is also apparent in the adaptive responses to a standardized exercise training program; some individuals show dramatic changes for a given variable (responders), whereas others show minimal effects (nonresponders) (24).

Determining the extent to which genetic and lifestyle factors influence age-associated functional declines and the magnitude of the adaptive responses to exercise (i.e., trainability) of both younger and older individuals is an area of active investigation. Exercise training studies involving families and twin pairs report a significant genetic influence on baseline physiological function (explaining ~30% to 70% of between-subjects variance) and trainability of aerobic fitness (24), skeletal muscle properties (199), and cardiovascular risk factors (24). Although the role of genetic factors in determining changes in function over time and in response to exercise training in older humans is not well understood, it is likely that a combination of lifestyle and genetic factors contribute to the wide interindividual variability seen in older adults.

Evidence statement and recommendation. *Evidence category B.* Individuals differ widely in how they age and in how they adapt to an exercise program. It is likely that a combination of genetic and lifestyle factors contribute to the wide interindividual variability seen in older adults.

Exercise and the aging process. The acute physiological adjustments of healthy sedentary older men and women to submaximal aerobic exercise are qualitatively similar to those of young adults and are adequate in meeting the major regulatory demands of exercise, which include the control of arterial blood pressure and vital organ perfusion, augmentation of oxygen and substrate delivery and utilization within active muscle, maintenance of arterial blood homeostasis, and dissipation of heat (213). The acute cardiovascular and neuromuscular adjustments to resistance exercise (both isometric and dynamic) also seem to be well preserved in healthy older adults (213). Accordingly, the normal age-associated reductions in functional capacity discussed in Section 1 should not limit the ability of healthy older adults to engage in aerobic or resistance exercise. In addition, long-term adaptive or training responses of middle-aged and nonfrail older adults to conventional AET or RET programs (i.e., relative intensity-based, progressive overload)

are qualitatively similar to those seen in young adults. Although absolute improvements tend to be less in older versus young people, the relative increases in many variables, including $\dot{V}O_{2max}$ (100), submaximal metabolic responses (211), and exercise tolerance with AET and limb muscle strength (139), endurance (255), and size (203) in response to RET, are generally similar. Physiological aging alters some of the mechanisms and time course (174,253) by which older men and women adapt to a given training stimulus (i.e., older adults may take longer to reach the same level of improvement), and sex differences are emerging with respect to these mechanisms (16), but the body's adaptive capacity is reasonably well-preserved, at least through the seventh decade (98,217). During the combined demands of large muscle exercise and heat and/or cold stress, however, older individuals do exhibit a greater reduction in exercise tolerance and an increased risk of heat and cold illness/injury, respectively, compared with young adults (126). Age differences in exercise tolerance at higher ambient temperatures may be at least partially due to the lower aerobic fitness levels in older adults (126). Cessation of aerobic training by older adults leads to a rapid loss of cardiovascular (184,210) and metabolic (201) fitness, whereas strength training-induced (neural) adaptations seem more persistent (139), similar to what has been observed in younger populations (44,139).

Evidence statement and recommendation. *Evidence category A.* Healthy older adults are able to engage in acute aerobic or resistance exercise and experience positive adaptations to exercise training.

Physical activity and successful aging. When centenarians and other long-lived individuals are studied, their longevity is often attributed to a healthy lifestyle. Three characteristic behaviors are routinely reported; these include exercising regularly, maintaining a social network, and maintaining a positive mental attitude (214,231). Physiological factors that are most frequently associated with longevity and successful aging include low blood pressure, low body mass index and central adiposity, preserved glucose tolerance (low plasma glucose and insulin concentrations), and an atheroprotective blood lipid profile consisting of low triglyceride and LDL-cholesterol and high HDL-cholesterol concentrations (97,231). Regular physical activity seems to be the only lifestyle behavior identified to date, other than perhaps caloric restriction, which can favorably influence a broad range of physiological systems and chronic disease risk factors (97,98), and may also be associated with better mental health (154) and social integration (155). Thus, despite large differences in genetic background among those of a given age cohort, it seems that physical activity may be a lifestyle factor that discriminates between individuals who have and have not experienced successful aging (207,214,258).

Evidence statement and recommendation. *Evidence category B/C.* Regular physical activity can favorably influence a broad range of physiological systems and may be a lifestyle

factor that discriminates between those individuals who have and have not experienced successful aging.

Physical activity and the prevention, management, and treatment of diseases and chronic conditions. There is growing evidence that regular physical activity reduces risk of developing numerous chronic conditions and diseases including cardiovascular disease, stroke, hypertension, type 2 diabetes mellitus, osteoporosis, obesity, colon cancer, breast cancer, cognitive impairment, anxiety, and depression. In addition, physical activity is recommended as a therapeutic intervention for the treatment and management of many chronic diseases including coronary heart disease (70,185,242), hypertension (37,183,241), peripheral vascular disease (157), type 2 diabetes (220), obesity (252), elevated cholesterol (165,241), osteoporosis (75,251), osteoarthritis (1,3), claudication (232), and chronic obstructive pulmonary disease (170). Furthermore, clinical practice guidelines also identify a role for physical activity in the treatment and management of conditions such as depression and anxiety disorders (26), dementia (54), pain (4), congestive heart failure (197), syncope (25), stroke (79), back pain (85), and constipation (142). Although a detailed review of the impact of regular physical activity on the development, treatment, and management of chronic diseases is beyond the scope of this Position Stand, Table 3 summarizes a growing body of evidence that regular physical activity reduces the risk of developing a large number of chronic diseases and is valuable in the treatment of numerous diseases.

Evidence statement and recommendation. *Evidence category A/B.* Regular physical activity reduces the risk of developing a large number of chronic diseases and conditions and is valuable in the treatment of numerous diseases.

SECTION 3: BENEFITS OF PHYSICAL ACTIVITY AND EXERCISE

This section summarizes published research with respect to the known benefits of exercise on functional capacity, chronic disease risk, and quality of life (QOL) in adults of various ages. The review considers first the effects of long-term participation in exercise by aerobic- and resistance-trained athletes, followed by a summary of the benefits of various modes of exercise training in previously sedentary individuals. The section concludes with a discussion of the benefits of physical activity and exercise training for psychological health, cognitive functioning, and overall QOL.

STUDIES OF LONG-TERM PHYSICAL ACTIVITY IN ATHLETES

Aerobic athletes. Compared to their sedentary, age-matched peers, older athletes exhibit a broad range of physiological and health advantages. These benefits include, but are not limited to the following: 1) a more favorable body composition profile, including less total and abdominal body fat (76,98), a greater relative muscle mass (% of body mass) in the limbs (235), and higher bone mineral density (BMD)

TABLE 3. Summary of the role of physical activity in the prevention, management, and treatment of chronic disease and disability.

Disease State	Preventive Role	Therapeutic Role	Effective Exercise Modality	Other Considerations
Arthritis	Possible, via prevention of obesity	Yes	AET RET Aquatic exercise	Low impact Sufficient volume to achieve healthy weight if obese
Cancer	Yes, AET in epidemiological studies	Yes, for QOL, wasting, lymphedema, psychological functioning, breast cancer survival	AET RET	
Chronic obstructive pulmonary disease	No	Yes, for extrapulmonary manifestations	AET RET	RET may be more tolerable in severe disease; combined effects complementary if feasible Time exercise sessions to coincide with bronchodilator medication peak Use oxygen during exercise as needed Exercise reduces cardiovascular and metabolic risk factors; improves depression RET offsets myopathy of chronic renal failure
Chronic renal failure	Possible, via prevention of diabetes and hypertension	Yes, for exercise capacity, body composition, sarcopenia, cardiovascular status, QOL, psychological function, inflammation, etc.	AET RET	
Cognitive impairment	Yes, AET in epidemiological studies	Yes	AET RET	Mechanism unknown Supervision needed for dementia
Congestive heart failure	Possible, via prevention of coronary artery disease and hypertension	Yes, for exercise capacity, survival, cardiovascular risk profile, symptoms, QOL	AET RET	RET may be more tolerable if dyspnea severely limits AET activity Cardiac cachexia targeted by RET
Coronary artery disease	Yes AET and RET now shown to be protective	Yes	AET RET	Complementary effects on exercise capacity and metabolic profile from combined exercise modalities Resistance may be more tolerable if ischemic threshold is very low because of lower HR response to training
Depression	Yes, AET in epidemiological studies	Yes	AET RET	Moderate- to high-intensity exercise more efficacious than low-intensity exercise in major depression Minor depression may respond to wider variety of exercise modalities and intensities
Disability	Yes, AET in epidemiological studies, muscle strength protective	Yes	AET RET	Choice of exercise should be targeted to etiology of disability
Hypertension	Yes, AET in epidemiological studies	Yes	AET RET	Small reductions in systolic and diastolic pressures seen Larger changes if weight loss occurs
Obesity	Yes, AET in epidemiological studies	Yes	AET RET	Sufficient energy expenditure to induce deficit RET maintains lean tissue (muscle and bone) better than AET during weight loss
Osteoporosis	Yes, AET in epidemiological studies	Yes	AET RET Balance training High-impact exercise	AET should be weight-bearing High-impact, high-velocity activity (e.g., jumping) if tolerable RET effects are local to muscles contracted Balance training should be added to prevent falls
Peripheral vascular disease	Yes, AET via treatment of risk factors for PVD related to exercise	Yes	AET Resistance	Vascular effect is systemic; upper limb ergometry may be substituted for leg exercise if necessary RET has positive but less robust effect on claudication May need to exercise to the limits of pain tolerance each session to extend time to claudication
Stroke	Yes, AET in epidemiological studies	Yes	AET, treadmill training RET (treatment)	Most effective treatment modality not clear
Type 2 diabetes	Yes, AET in epidemiological studies RET protective for impaired glucose tolerance	Yes	AET RET (treatment)	Exercise every 72 h Moderate- to high-intensity exercise most effective

AET, aerobic exercise training; RET, resistance exercise training; QOL, quality of life.

at weight bearing sites (78,164); 2) more oxidative and fatigue-resistant limb muscles (98,188,247); 3) a higher capacity to transport and use oxygen (173,189,206); 4) a higher cardiac stroke volume at peak exertion (77,173) and a “younger” pattern of left ventricular filling (increased early-to-late inflow velocity, E/A ratio) (55,98); 5) less cardiovascular (83) and metabolic (38,206,211,212) stress during exercise at any given submaximal work intensity; 6) a significantly reduced coronary risk profile (lower blood pressure, increased HR variability, better endothelial reactivity, lower systemic inflammatory markers, better insulin sensitivity and glucose homeostasis, lower triglycerides, LDL, and total cholesterol, higher HDL, and smaller

waist circumference) (264); 7) faster nerve conduction velocity (253); and 8) slower development of disability in old age (257).

Evidence statement and recommendation. *Evidence category B.* Vigorous, long-term participation in AET is associated with elevated cardiovascular reserve and skeletal muscle adaptations that enable the aerobically trained older individual to sustain a submaximal exercise load with less cardiovascular stress and muscular fatigue than their untrained peers. Prolonged aerobic exercise also seems to slow the age-related accumulation of central body fat and is cardioprotective.

Resistance-trained athletes. The number of laboratory-based physiological comparisons of resistance-trained

athletes at various ages is small by comparison to the literature on aging aerobic athletes. Nevertheless, older RET athletes tend to have a higher muscle mass (131), are generally leaner (217), and are ~30%–50% stronger (131) than their sedentary peers. Compared to age-matched AET athletes, RET athletes have more total muscle mass (131), higher bone mineral densities (236), and maintain higher muscle strength and power (131).

Evidence statement and recommendation. *Evidence category B.* Prolonged participation in RET has clear benefits for slowing the loss of muscle and bone mass and strength, which are not seen as consistently with aerobic exercise alone.

BENEFITS OF EXERCISE TRAINING IN PREVIOUSLY SEDENTARY INDIVIDUALS

AET

Aerobic exercise capacity. Supervised AET programs of sufficient intensity ($\geq 60\%$ of pretraining $\dot{V}O_{2\max}$), frequency (≥ 3 d \cdot wk $^{-1}$), and length (≥ 16 wk) can significantly increase $\dot{V}O_{2\max}$ in healthy middle-aged and older adults. The average increase in $\dot{V}O_{2\max}$ reported in well-controlled studies lasting 16 to 20 wk is $+3.8$ mL \cdot kg $^{-1}\cdot$ min $^{-1}$ or 16.3% when compared with nonexercise control subjects during the same period. Larger improvements in $\dot{V}O_{2\max}$ are typically observed with longer training periods (20 to 30 wk) but not necessarily higher training intensities (i.e., $>70\%$ of $\dot{V}O_{2\max}$) (100), unless an interval-type training regimen is used (5,145). Significant AET-induced increases in $\dot{V}O_{2\max}$ have also been reported in healthy subjects older than 75 yr, but the magnitude of improvement is significantly less (60,146). Although men and women in their 60s and early 70s show similarly relative (% above pretraining) increases in $\dot{V}O_{2\max}$ after AET compared with younger adults, there seems to be a sex difference in the underlying mechanisms of adaptation; older men exhibit increases in maximal cardiac output and systemic arteriovenous O_2 difference, whereas older women rely almost exclusively on widening the systemic arteriovenous O_2 difference (228).

Evidence statement and recommendation. *Evidence category A.* AET programs of sufficient intensity ($\geq 60\%$ of pretraining $\dot{V}O_{2\max}$), frequency, and length (≥ 3 d \cdot wk $^{-1}$ for ≥ 16 wk) can significantly increase $\dot{V}O_{2\max}$ in healthy middle-aged and older adults.

Cardiovascular effects. Three or more months of moderate-intensity AET (e.g., $\geq 60\%$ of $\dot{V}O_{2\max}$) elicits several cardiovascular adaptations in healthy (normotensive) middle-aged and older adults, which are evident at rest and in response to acute dynamic exercise. The most consistently reported adaptations include the following: 1) a lower HR at rest (101) and at any submaximal exercise workload (84); 2) smaller rises in systolic, diastolic, and mean blood pressures during submaximal exercise (212);

3) improvements in the vasodilator and O_2 uptake capacities of the trained muscle groups (116,149,267); and 4) numerous cardioprotective effects, including reductions in atherogenic risk factors (reduced triglyceride and increased HDL concentrations), reductions in large elastic artery stiffness (239), improved endothelial (49) and baroreflex (174) function, and increased vagal tone (174). Evidence for improved myocardial contractile performance (i.e., left ventricular systolic and diastolic function), increased maximal exercise stroke volume, and cardiac hypertrophy after AET has generally been limited to studies involving men (59,210,229,234) and at higher intensities of training (145).

Evidence statement and recommendation. *Evidence category A.* Three or more months of moderate-intensity AET elicits cardiovascular adaptations in healthy middle-aged and older adults, which are evident at rest and in response to acute dynamic exercise.

Body composition. Sedentary Americans typically gain 8 to 9 kg of body weight (mostly fat gain) between the ages of 18 and 55 yr (98); this is followed by additional gains of 1 to 2 kg over the next decade and declining body weight thereafter (76). In studies involving overweight middle-aged and older adults, moderate-intensity AET ($\geq 60\%$ of $\dot{V}O_{2\max}$) without dietary modification has generally been shown to be effective in reducing total body fat. Average losses during 2 to 9 months ranged from 0.4 to 3.2 kg (1%–4% of total body weight) (123,244) with the magnitude of total fat loss related to the total number of exercise sessions (80), just as in younger overweight populations. Although these reductions in total fat may seem modest in relation to age-related weight gain, AET can have significant effects on fat loss from the intra-abdominal (visceral) region (e.g., $>20\%$) (107).

In contrast to its effects on body fat, most studies report no significant effect of AET on fat-free mass (FFM). A meta-analysis identified significant increases in total FFM in only 8 of 36 studies that involved AET, and these increases were generally less than 1 kg (244). The lack of impact on FFM accretion by AET reflects the fact that this form of training, which involves repetitive, but low-force muscular contractions, does not generally stimulate significant skeletal muscle growth or improve strength.

Evidence statement and recommendation. *Evidence category A/B.* In studies involving overweight middle-aged and older adults, moderate-intensity AET has been shown to be effective in reducing total body fat. In contrast, most studies report no significant effect of AET on FFM.

Metabolic effects. AET, independent of dietary changes, can induce multiple changes that enhance the body's ability to maintain glycemic control at rest (98,129), to clear atherogenic lipids (triglycerides) from the circulation after a meal (121), and to preferentially use fat as a muscular fuel during submaximal exercise (219). Healthy men and women in their 60s and 70s seem to retain the capacity to upregulate the cellular processes that facilitate these respective training effects. However, the impact of

AET on metabolic control measured at the whole body level and the residual metabolic effects after exercise (throughout the day) may depend on the *intensity* of the training stimulus. For example, although both moderate- (218) and high-intensity (43) AET are shown to increase glucose transporter content in the muscles of older humans, it is the higher-intensity AET programs that may result in greater improvement in whole-body insulin action (52).

Evidence statement and recommendation. *Evidence category B.* AET can induce a variety of favorable metabolic adaptations including enhanced glycemic control, augmented clearance of postprandial lipids, and preferential utilization of fat during submaximal exercise.

Bone health. Low-intensity weight bearing activities such as walking ($3\text{--}5\text{ d}\cdot\text{wk}^{-1}$) for periods of up to 1 yr have modest, if any, effect on BMD in postmenopausal women (0%–2% increase in hip, spine BMD) (132). However, such activities seem beneficial from the standpoint of counteracting age-related losses (0.5 to $1\%\cdot\text{yr}^{-1}$ in sedentary controls) and lowering hip fracture risk (7,132). Studies involving higher-intensity bone loading activities such as stair climbing/descending, brisk walking, walking with weighted vests, or jogging, generally report more significant effects on BMD in postmenopausal women (132), at least during the short term (1 to 2 yr). Research on the effectiveness of exercise for bone health in older men is still emerging (125), but one prospective study found that middle aged and older men who ran nine or more times per month exhibited lower rates of lumbar bone loss than men who jogged less frequently (161).

Evidence statement and recommendation. *Evidence category B.* AET may be effective in counteracting age-related declines in BMD in postmenopausal women.

RET

Muscular strength. Changes in strength after RET are assessed using a variety of methods, including isometric, isokinetic, one-repetition maximum (1-RM), and multiple-repetition (e.g., 3-RM) maximum-effort protocols. In general, strength increases after RET in older adults seem to be greater with measures of 1-RM or 3-RM performance compared with isometric or isokinetic measures (64,73,102,172). Older adults can substantially increase their strength after RET—with reported increases ranging from less than 25% (34,64,82,89,91) to greater than 100% (63,66,73,140). The influence of age on the capacity to increase strength after RET is complex. Several studies have demonstrated similar percent strength gains between older and younger participants (89,91,99,114,169), whereas others have reported that percent strength increases are less for older compared with younger adults (139,144). Additional reports suggest that the effects of age on strength adaptations may be influenced by gender (109), duration of the training intervention (112), and/or the specific muscle groups examined (259).

Evidence statement and recommendation. *Evidence category A.* Older adults can substantially increase their strength after RET.

Muscle power. Power production is equivalent to the force or torque of a muscular contraction multiplied by its velocity. Studies suggest that *power*-producing capabilities are more strongly associated with functional performance than *muscle strength* in older adults (11,57,60,71,227). Moreover, the age-related loss of muscle power occurs at a greater rate than the loss of strength (23,88,93,111,159) most likely owing to a disproportionate reduction in the size of Type II fibers (130,140). However, substantial increases in power (measured using isokinetic, isotonic, stair climbing, and vertical jumping protocols) are demonstrated after RET in older adults (58,64,67,68,112,169). Several earlier studies reported greater increases in maximum strength compared with power (67,115,227); however, the training protocols in these studies used traditional, slower-movement speeds. More recent studies, incorporating higher-velocity training protocols, suggest that the gains in power may be either comparable (58,112,169) or greater (68) to gains in maximum strength/force production.

Evidence statement and recommendation. *Evidence category A.* Substantial increases in muscular power have been demonstrated after RET in older adults.

Muscle quality. Muscle quality (MQ) is defined in muscular performance (strength or power) per unit muscle volume or mass. Understanding the effects of RET on MQ in older adults is important because most studies suggest that increases in strength and power after RET are greater than would be expected based upon changes in muscle mass alone (8,73,110,246). These findings are magnified during the earlier phases of training (91,163). Although increased motor unit recruitment and/or discharge rates are thought to be the primary contributors to increased MQ after RET (42,82,89,91,144), other factors including decreased activation of antagonistic muscle groups (89,91), alterations in muscle architecture and tendon stiffness (193–195), and selective hypertrophy of Type II muscle fiber areas (36,92,148) may also influence MQ. Although the hypertrophic response is diminished in older adults, increases in MQ are similar between older and younger men (110,259) but may be greater in younger women compared with older women (90). Improvements in MQ do not seem to be sex-specific, and adaptations after RET seem to be similar between older men and women (91,246).

Evidence statement and recommendation. *Evidence category B.* Increases in MQ are similar between older and younger adults, and these improvements do not seem to be sex-specific.

Muscle endurance. Although the ability to repeatedly produce muscular force and power over an extended period may determine an older adult's travel range and functional independence, the effects of RET on muscular endurance are relatively understudied. Increases in muscular strength, secondary to neurological, metabolic, and/or hypertrophic

adaptations, are likely to translate into increased muscular endurance by 1) reducing the motor-unit activation required to complete submaximal tasks (104,136), 2) reducing the coactivation of antagonistic muscles (75,91), 3) increasing high-energy phosphate (adenosine triphosphate and creatine phosphate) availability (103), 4) shifting the expression of myosin heavy chain isoforms from IIb (IIx) to IIa (215), 5) increasing mitochondrial density and oxidative capacity (116), and 6) reducing the percent of available myofiber volume required to complete submaximal tasks. Marked improvements (34%–200%) in muscular endurance have been reported after RET using moderate- to higher-intensity protocols (2,82,255).

Evidence statement and recommendation. *Evidence category C.* Improvements in muscular endurance have been reported after RET using moderate- to higher-intensity protocols, whereas lower-intensity RET does not improve muscular endurance.

Body composition. Most studies report an increase in FFM with high-intensity RET. Men tend to have greater increase in FFM after RET than women, but these sex differences are no longer seen when FFM is expressed relative to initial FFM (102). Although some have suggested that this increase in FFM is primarily due to an increase in total body water (33), both muscle tissue and bone are also affected by RET. Increases in FFM can be attributed to increases in muscle cross-sectional areas (203,248) and volumes (203). These changes seem to be a result of an increase in Type IIa fiber areas, with a decrease in Type IIx fiber area (8) and no change in Type I fiber area (36). A recent review (103) of 20 studies found that older adults demonstrate hypertrophy of muscle tissue of between 10% and 62% after RET.

Several studies have found that moderate- or high-intensity RET decreases total body fat mass (FM), with losses ranging from 1.6% to 3.4% (8,33,102,105,106,108,114,249). Recently, investigators have attempted to determine the effect of RET on *regional* FM—specifically subcutaneous adipose tissue (SAT) and intra-abdominal adipose tissue (IAAT). Binder et al. (17) reported no change in IAAT or SAT in frail older adults after 12 wk of RET; however, Hunter et al. (102) reported sex-specific effects—demonstrating that elder women, but not men, lost IAAT (12%) and SAT (6%) after 25 wk of moderate-intensity (65%–80% 1-RM) RET. Others reported that both older men and women decreased IAAT by 10% (108,248) after 16 wk of RET.

Evidence statement and recommendation. *Evidence category B/C.* Favorable changes in body composition, including increased FFM and decreased FM have been reported in older adults who participate in moderate or high intensity RET.

Bone health. Several meta-analyses have concluded that RET as well as AET have significant positive effects on BMD in most sites in both pre- and postmenopausal women (124,125,256,266). In general, 1%–2% differences between RET and sedentary controls are seen in RCTs in which RET

conforms to the principles known to be associated with skeletal adaptation, namely, higher intensity, progressive, and novel loading, as well as high strain rates. For example, Vincent and Braith (254) reported a 1.96% increase in BMD at the femoral neck, with no significant changes in total body, spine, or Ward's Triangle BMD—after high-intensity, low-volume RET of 24 wk in duration. However, other studies have demonstrated more modest effects. For example, Stewart et al. (233) reported that group data inferred a *decrease* in average BMD with combined low-intensity RET and aerobic training; however, regression modeling revealed a positive relation between increases in strength and increases in femoral BMD. Rhodes et al. (198) also reported significant correlations (0.27–0.40) between changes in leg strength and femoral and lumbar BMD changes; however, they too found no between-group differences in controls and exercisers who performed 12 months of RET (75% 1-RM; 3 d·wk⁻¹).

Evidence statement and recommendation. *Evidence category B.* High-intensity RET preserves or improves BMD relative to sedentary controls, with a direct relationship between muscle and bone adaptations.

Metabolic and endocrine effects. The effects of short- and long-term RET programs on basal metabolic rate (BMR) in older adults are not clear. Some investigations have reported increases of 7%–9% in BMR after 12–26 wk of exercise (33,105,139,249), whereas other studies of similar duration have not demonstrated changes (158,237). RET programs can enhance older adults' use of fat as a fuel, as indicated by increased lipid oxidation and decreased carbohydrate and amino acid oxidation at rest (105,249). Serum cholesterol and triglycerides are also influenced by RET, and reports suggest that training can increase HDL cholesterol by 8%–21%, decrease LDL cholesterol by 13%–23%, and reduce triglyceride levels by 11%–18% (62,86,114).

Resting testosterone is lower in older adults, and acute responses of total and free testosterone to weight lifting are blunted in seniors after RET. Neither short- (10–12 wk) (45,112,135) nor longer-term (21–24 wk) (22,87) RET increases resting concentrations of total or free testosterone. A decrease in resting cortisol (15%–25%) (112,133), however, has previously been observed, which may create a favorable environment for muscle hypertrophy. Peptide hormones, including growth hormone and insulin-like growth factor 1 (IGF-1) also have important anabolic action. Circulating growth hormone stimulates synthesis of IGF-1 in the liver, and circulating IGF-1 promotes differentiation of satellite cells into myotubes (95). Another IGF, mechanogrowth factor, is synthesized locally in muscle and signals the proliferation of satellite cells (94). Although one report suggests that RET may increase circulating IGF-1 in participants with low baseline serum IGF-1 levels (178), most investigations suggest that RET does not alter circulating IGF-1 (8,15,22,89). RET also seems to have no effect on free IGF-1 (15) and does not decrease IGF-1 binding proteins (22,178).

Evidence statement and recommendation. *Evidence category B/C.* Evidence of the effect of RET on metabolic variables is mixed. There is some evidence that RET can alter the preferred fuel source used under resting conditions, but there is inconsistent evidence regarding the effects of RET on BMR. The effect of RET on a variety of different hormones has been studied increasingly in recent years; however, the exact nature of the relationship is not yet well understood.

Balance Training

Several studies have examined relationships among age, exercise, and balance with the most research having been conducted in populations at risk for falling (i.e., osteoporotic women, frail older adults, subjects with a previous fall history) (231). Several large prospective cohort studies link higher levels of physical activity, particularly walking, with 30%–50% reduction in the risk of osteoporotic fractures (74). However, these studies do not provide data on the utility of balance training alone for achieving this outcome. Nonetheless, balance training activities such as lower body strengthening and walking over difficult terrain have been shown to significantly improve balance in many studies, and are thus recommended as part of an exercise intervention to prevent falls (74,21,181,204). Older adults identified at the highest risk for falls seem to benefit from an individually tailored exercise program that is embedded within a larger, multifactorial falls-prevention intervention (243,48,202). Multimodal programs of balance, strength, flexibility, and walking (30–32,171) are shown to reduce the risk of both noninjurious and injurious falls. In addition, there is some evidence that tai chi programs can be effective in reducing the risk of both noninjurious and injurious falls (141,265).

Evidence statement and recommendation. *Evidence category C.* Multimodal exercise, usually including strength and balance exercises, and tai chi have been shown to be effective in reducing the risk of noninjurious and sometimes injurious falls in populations who are at an elevated risk of falling.

Stretching and flexibility training. Despite decrements in joint ROM with age and established links among poor flexibility, mobility, and physical independence (16,222,262), there remains a surprisingly small number of studies that have documented or compared the effects of specific ROM exercises on flexibility outcomes in older populations. One well-controlled study of 70-yr-old women reported significant improvements in low back/hamstring flexibility (+25%) and spinal extension (+40%) after 10 wk of a supervised static stretching program (3 d·wk⁻¹) that involved a series of low back and hip exercises (200). Improvements of a similar magnitude have been documented for upper body (i.e., shoulder) and lower body (ankle, knee) flexibility in older men and women using a combination of stretching and rhythmic movements through full ROM (e.g., stretching + yoga or tai chi) (231). Collectively, these results suggest that flexibility can be increased in the major joints by ROM exercises *per se* in healthy older adults. However, there is little consensus regarding how much (frequency,

duration) and what types of ROM exercises (static vs dynamic) are the safest and most effective for older adults.

Evidence statement and recommendation. *Evidence category D.* Few controlled studies have examined the effect of flexibility exercise on ROM in older adults. There is some evidence that flexibility can be increased in the major joints by ROM exercises; however, how much and what types of ROM exercises are most effective have not been established.

Effect of exercise and physical activity on physical functioning and daily life activities. The degree to which participation in exercise and physical activity translates into improved physical functioning and enhanced performance of everyday life activities is not yet clear. Contrasting findings of *improved* versus *unchanged* physical performance after a variety of exercise activities (e.g., walking, stair climbing, balance, chair standing) have been reported, and there is not a simple linear relationship between participation in physical activity and changes in disability (i.e., dependence in ADL). For example, improvements of between 7% and 17% have been demonstrated for self-selected and/or maximum-effort walking velocity after a variety of RET programs (13,90,96,99,118,208,226); however, nonsignificant changes have also been reported after lower- and higher-intensity interventions (27,28,58,80,117). Although some studies demonstrated improvements across a variety of functional tasks (12,13,96,99,162,255), other studies suggest functional performance adaptations are more specific, resulting in changes in one functional measure (e.g., walking) but not others (e.g., chair-rise or stair climb performance) (208). Nonetheless, there does seem to be a relationship between maintaining cardiovascular fitness levels and the likelihood of becoming functionally dependent in an 8-yr follow-up study of older adults (180). The nature and strength of the relationship between physical activity and functional performance are likely to vary as a function of the specific physical activity functional measures selected (205,227). Furthermore, because *specificity of training* principles suggest that performance adaptations will be greatest for those activities that mimic the kinematics, resistances, and movement speeds used in the training program, many authors have emphasized the importance of prescribing higher-velocity movements using activities that mimic ADL (10,13,47,60,162).

Evidence statement and recommendation. *Evidence category C/D.* The effect of exercise on physical performance is poorly understood and does not seem to be linear. RET has been shown to favorably impact walking, chair stand, and balance activities, but more information is needed to understand the precise nature of the relationship between exercise and functional performance.

BENEFITS OF EXERCISE AND PHYSICAL ACTIVITY FOR PSYCHOLOGICAL HEALTH AND WELL-BEING

In addition to its effects on physiological variables and a variety of chronic diseases and conditions, there is now strong

evidence that exercise and physical activity have a significant impact on several psychological parameters. In this revision of the ACSM Position Stand “Exercise and Physical Activity for Older Adults,” we update the previous edition of the Position Stand with respect to new evidence regarding the effect of participation in regular physical activity on overall psychological health and well-being, the effect of exercise and physical activity on cognitive functioning, and the impact of exercise and physical activity on overall QOL. In addition, for the first time, we include a separate section that focuses on a relatively new literature that examines the effect of RET on psychological health and well-being.

Physical activity and psychological well-being in aging. There is now considerable evidence that regular physical activity is associated with significant improvements in overall psychological health and well-being (155,231). Both higher physical fitness (20,29,221) and participation in AET are associated with a decreased risk for clinical depression or anxiety (20,56,153). Exercise and physical activity have been proposed to impact psychological well-being through their moderating and mediating effects on constructs such as self-concept and self-esteem (72). However, other pathways may also be operative, such as reduction in visceral adiposity along with associated elevation in cortisol (186) and inflammatory adipokines (263,269) that have been implicated in hippocampal atrophy, cognitive, and affective impairments (143). In addition, for many seniors, aging is associated with a loss of perceived control (9). Because perceptions of control over one’s own life are known to be related to psychological health and well-being, exercise scientists have begun to focus on the relationship between activity and various indices of psychosocial control, self-efficacy, and perceived competency (156). McAuley and Katula (155) reviewed the literature examining the relationship between physical activity and self-efficacy in older adults. They conclude that most well-controlled exercise training studies result in significant improvements in both physical fitness and self-efficacy for physical activity in older adults. Several studies suggest that moderate-intensity physical activity may be more effective than either low- or high-intensity training regimens (128,154). There is growing recognition that physical activity self-efficacy is not only an important outcome measure as a result of participation in activity, it may also be an important predictor of sustained behavioral change in sedentary populations (56).

Evidence statement and recommendation. *Evidence category A/B.* Regular physical activity is associated with significant improvements in overall psychological well-being. Both physical fitness and AET are associated with a decreased risk for clinical depression or anxiety. Exercise and physical activity have been proposed to impact psychological well-being through their moderating and mediating effects on constructs such as self-concept and self-esteem.

Physical activity, cognitive functioning, and aging. Both cross-sectional and prospective cohort studies

have linked participation in regular physical activity with a reduced risk for dementia or cognitive decline in older adults. Examples include the Study of Osteoporotic Fractures (268), which reported that activity level was linked to changes in Mini-Mental Status Examination scores, and the Canadian Study of Health and Aging, which demonstrated that physical activity was associated with lower risk of cognitive impairment and dementia (138). It also seems that decreases in physical mobility are linked to cognitive decline (127). The InCHIANTI study reported an association between physical mobility, specifically walking speed and ability to walk 1 km, with signs of neurological disease (65). Similarly, the Oregon Brain Aging Study reported an association between walking speed and onset of cognitive impairment (147). Finally, the MacArthur Research Network on Successful Aging Community Study reported associations between declines in cognitive performance and routine physical tasks including measures of grip strength and mobility (i.e., walking speed, chair stands) (238).

Experimental trials of exercise interventions in older adults demonstrate that acute exposure to a single bout of aerobic exercise can result in short-term improvements in memory, attention, and reaction time (39), but more importantly, participation in both AET and RET alone, and in combination, leads to sustained improvements in cognitive performance, particularly for executive control tasks (39). Several studies have compared the individual and combined effects of physical and mental exercise interventions (61,177). These studies found cognitive benefits to be larger with the combined cognitive and aerobic training paradigms. The mechanism for the relationship between physical activity and exercise and cognitive functioning is not well understood; however, several researchers have suggested that enhanced blood flow, increased brain volume, elevations in brain-derived neurotrophic factor, and improvements in neurotransmitter systems and IGF-1 function may occur in response to behavioral and aerobic training (40,134).

Evidence statement and recommendation. *Evidence category A/B.* Epidemiological studies suggest that cardiovascular fitness and higher levels of physical activity reduce the risk of cognitive decline and dementia. Experimental studies demonstrate that AET, RET, and especially combined AET and RET can improve cognitive performance in previously sedentary older adults for some measures of cognitive functioning but not others. Exercise and fitness effects are largest for tasks that require complex processing requiring executive control.

Physical activity and QOL in old age. QOL is a psychological construct, which has commonly been defined as a conscious judgment of the satisfaction an individual has with respect to his/her own life (182). In a review of the literature that has examined the relationship between physical activity and QOL in old age, Rejeski and Mihalko (196) conclude that the bulk of the evidence supports the conclusion that physical activity seems to be positively associated with many

but not all domains of QOL. Researchers have consistently shown that when physical activity is associated with significant increases in self-efficacy, improvements in health-related QOL are most likely to occur (155).

Evidence statement and recommendation. *Evidence category D.* Although physical activity seems to be positively associated with some aspects of QOL, the precise nature of the relationship is poorly understood.

Effects of RET on psychological health and well-being. Recent reviews suggest that RET can improve

several indices of psychological health and well-being including anxiety, depression, overall well-being, and QOL (6,168,230,240). The randomized controlled trial evidence for RET as an isolated intervention for the treatment of clinical depression in both younger and older cohorts is robust and consistent. Both AET (81,151,153) and RET (150,224,225) produce clinically meaningful improvements in depression in clinical patients, with response rates ranging from 25% to 88%. Studies are less consistent among seniors without clinical depression. For

TABLE 4. Summary of the SORT evidence strength taxonomy.

Evidence Statements	Evidence Strength: A = Highest, D = Lowest
Section 1: Normal human aging	
<i>Advancing age is associated with physiologic changes that result in reductions in functional capacity and altered body composition.</i>	A
<i>Advancing age is associated with declines in physical activity volume and intensity.</i>	A/B ^a
<i>Advancing age is associated with increased risk for chronic diseases but physical activity significantly reduces this risk.</i>	B
Section 2: Physical activity and the aging process	
<i>Regular physical activity increases average life expectancy through its influence on chronic disease development, through the mitigation of age-related biological changes and their associated effects on health and well-being, and through the preservation of functional capacity.</i>	A
<i>Individuals differ widely in how they age and in how they adapt to an exercise program. It is likely that lifestyle and genetic factors contribute to the wide interindividual variability seen in older adults.</i>	B
<i>Healthy older adults are able to engage in acute aerobic or resistance exercise and experience positive adaptations to exercise training.</i>	A
<i>Regular physical activity can favorably influence a broad range of physiological systems and may be a major lifestyle factor that discriminates between those individuals who have and have not experienced successful aging.</i>	B/C ^a
<i>Regular physical activity reduces the risk of developing a large number of chronic diseases and conditions and is valuable in the treatment of numerous diseases.</i>	A/B ^a
Section 3: Benefits of physical activity and exercise	
<i>Vigorous, long-term participation in AET is associated with elevated cardiovascular reserve and skeletal muscle adaptations, which enable the aerobically trained older individual to sustain a submaximal exercise load with less cardiovascular stress and muscular fatigue than their untrained peers. Prolonged aerobic exercise also seems to slow the age-related accumulation of central body fat and is cardioprotective.</i>	B
<i>Prolonged participation in RET is consistently associated with higher muscle and bone mass and strength, which are not seen as consistently seen with prolonged AET alone.</i>	B
<i>AET programs of sufficient intensity ($\geq 60\%$ of pretraining $\dot{V}O_{2max}$), frequency, and length (≥ 3 d\cdotwk⁻¹ for ≥ 16 wk) can significantly increase $\dot{V}O_{2max}$ in healthy middle-aged and older adults.</i>	A
<i>Three or more months of moderate-intensity AET elicits cardiovascular adaptations in healthy middle-aged and older adults, which are evident at rest and in response to acute dynamic exercise.</i>	A/B ^a
<i>In studies involving overweight middle-aged and older adults, moderate-intensity AET has been shown to be effective in reducing total body fat. In contrast, most studies report no significant effect of AET on FFM.</i>	A/B ^a
<i>AET can induce a variety of favorable metabolic adaptations including enhanced glycemic control, augmented clearance of postprandial lipids, and preferential utilization of fat during submaximal exercise.</i>	B
<i>AET may be effective in counteracting age-related declines in BMD in postmenopausal women</i>	B
<i>Older adults can substantially increase their strength after RET.</i>	A
<i>Substantial increases in muscular power have been demonstrated after RET in older adults.</i>	A
<i>Increases in MQ are similar between older and younger adults, and these improvements do not seem to be sex-specific.</i>	B
<i>Improvements in muscular endurance have been reported after RET using moderate- to higher-intensity protocols, whereas lower-intensity RET does not improve muscular endurance.</i>	C
<i>The effect of exercise on physical performance is poorly understood and does not seem to be linear. RET has been shown to favorably impact walking, chair stand, and balance activities, but more information is needed to understand the precise nature of the relationship between exercise and functional performance</i>	C/D ^a
<i>Favorable changes in body composition, including increased FFM and decreased FM have been reported in older adults who participate in moderate or high intensity RET.</i>	B/C
<i>High-intensity RET preserves or improves BMD relative to sedentary controls, with a direct relationship between muscle and bone adaptations.</i>	B
<i>Evidence of the effect of RET on metabolic variables is mixed. There is some evidence that RET can alter the preferred fuel source used under resting conditions, but there is inconsistent evidence regarding the effects of RET on BMR. The effect of RET on a variety of different hormones has been studied increasingly in recent years; however, the exact nature of the relationship is not yet well understood.</i>	B/C
<i>Multimodal exercise, usually including strength and balance exercises, and tai chi have been shown to be effective in reducing the risk of noninjurious and sometimes injurious falls in populations who are at an elevated risk of falling.</i>	C
<i>Few controlled studies have examined the effect of flexibility exercise on ROM in older adults. There is some evidence that flexibility can be increased in the major joints by ROM exercises; however, how much and what types of ROM exercises are most effective have not been established.</i>	D
<i>Regular physical activity is associated with significant improvements in overall psychological well-being. Both physical fitness and AET are associated with a decreased risk for clinical depression or anxiety. Exercise and physical activity have been proposed to impact psychological well-being through their moderating and mediating effects on constructs such as self-concept and self-esteem.</i>	A/B
<i>Epidemiological studies suggest that cardiovascular fitness and higher levels of physical activity reduce the risk of cognitive decline and dementia. Experimental studies demonstrate that AET, RET, and especially combined AET and RET can improve cognitive performance in previously sedentary older adults for some measures of cognitive functioning but not others. Exercise and fitness effects are largest for tasks that require complex processing requiring executive control.</i>	A/B
<i>Although physical activity seems to be positively associated with some aspects of QOL, the precise nature of the relationship is poorly understood.</i>	D
<i>There is a strong evidence that high-intensity RET is effective in the treatment of clinical depression. More evidence is needed regarding the intensity and frequency of RET needed to elicit specific improvements in other measures of psychological health and well-being.</i>	A/B

^a Any review of evidence pertaining to exercise and physical activity in older adult populations will necessarily be interdisciplinary and subject to differences in research design across various subdisciplines within exercise science. Whenever possible, a single SORT rating is provided; however, occasionally, when the strength of evidence varies across studies, a composite rating is provided.

example, symptoms of depression did not improve after light-resistance elastic band training in frail community-dwelling seniors without clinical symptoms (35). Mean depression scores also did not improve in healthy, independent but sedentary older women after either moderate- or higher-intensity RET using weight machines; however, anxiety levels did decrease after moderate-intensity RET (250). Improvements in overall well-being and QOL measures (e.g., body pain, vitality, social functioning, morale, and/or sleep quality) have also been reported after RET using moderate- and higher-intensity protocols in community-dwelling seniors with minor or major depression (223) and in independent sedentary older women (250). In contrast, low-intensity task-unspecific protocols may not be effective in improving QOL measures in healthy independent seniors (80,154).

Evidence statement and recommendation. *Evidence category A/B.* There is a strong evidence that high-intensity RET is effective in the treatment of clinical depression. More evidence is needed regarding the intensity and frequency of RET needed to elicit specific improvements in other measures of psychological health and well-being.

CONCLUSIONS

Although no amount of physical activity can stop the biological aging process, there is evidence that regular exercise can minimize the physiological effects of an otherwise sedentary lifestyle and increase active life expectancy by limiting the development and progression of chronic disease and disabling conditions. There is also emerging evidence for psychological and cognitive benefits accruing from regular exercise participation by older adults (Table 4). It is not yet possible to describe in detail exercise programs that will optimize physical functioning and health in all groups of older adults. New evidence also suggests that some of the adaptive responses to exercise training are genotype-sensitive, at least in animal studies (14). Nevertheless, several evidence-based conclusions can be drawn relative to exercise and physical activity in the older adult population: 1) A combination of AET and RET activities seems to be more effective than either form of training alone in counteracting the detrimental effects of a sedentary lifestyle on the health and functioning of the cardiovascular system and skeletal muscles. 2) Although

there are clear fitness, metabolic, and performance benefits associated with higher-intensity exercise training programs in healthy older adults, it is now evident that such programs do not need to be of high intensity to reduce the risks of developing chronic cardiovascular and metabolic disease. However, the outcome of treatment of some established diseases and geriatric syndromes is more effective with higher-intensity exercise (e.g., type 2 diabetes, clinical depression, osteopenia, sarcopenia, muscle weakness). 3) The acute effects of a single session of aerobic exercise are relatively short-lived, and the chronic adaptations to repeated sessions of exercise are quickly lost upon cessation of training, even in regularly active older adults. 4) The onset and patterns of physiological decline with aging vary across physiological systems and between sexes, and some adaptive responses to training are age- and sex-dependent. Thus, the extent to which exercise can reverse age-associated physiological deterioration may depend, in part, on the hormonal status and age at which a specific intervention is initiated. 5) Ideally, exercise prescription for older adults should include aerobic exercise, muscle strengthening exercises, and flexibility exercises. In addition, individuals who are at risk for falling or mobility impairment should also perform specific exercises to improve balance in addition to the other components of health-related physical fitness. The conclusions of this Position Stand are highly consistent with the recently published *2008 Physical Activity Guidelines for Americans*, which state that regular physical activity is essential for healthy aging. Adults aged 65 yr and older gain substantial health benefits from regular physical activity, and these benefits continue to occur throughout their lives. Promoting physical activity for older adults is especially important because this population is the least physically active of any age group (50).

The writing group would like to acknowledge the contributions of Drs. Loren Chiu (Metabolic Effects), Sean Flanagan (Body Composition), Beth Parker (Stretching and Flexibility training), and Kevin Short (Metabolic effects) who provided assistance in the preparation of sections of the Position Stand.

This pronouncement was reviewed by the American College of Sports Medicine Pronouncements Committee and by Gareth R. Jones, Ph.D.; Priscilla G. MacRae, Ph.D., FACSM; Miriam C. Morey, Ph.D.; Anthony A. Vandervoort, Ph.D., FACSM; and Kevin R. Vincent, M.D., Ph.D.

This Position Stand replaces the 1998 ACSM Position Stand, "Exercise and Physical Activity for Older Adults." *Med Sci Sports Exerc.* 1998;30(6):992–1008.

REFERENCES

1. ACRSO. Recommendations for the medical management of osteoarthritis of the hip and knee: 2000 update. American College of Rheumatology Subcommittee on Osteoarthritis Guidelines. *Arthritis Rheum.* 2000;43(9):1905–15.
2. Adams KJ, Swank AM, Berning JM, Sevene-Adams PG, Barnard KL, Shimp-Bowerman J. Progressive strength training in sedentary, older African American women. *Med Sci Sports Exerc.* 2001;33(9):1567–76.
3. AGS. American Geriatrics Society Panel on Exercise and Osteoarthritis. Exercise prescription for older adults with osteoarthritis pain: consensus practice recommendations. A supplement to the AGS Clinical Practice Guidelines on the management of chronic pain in older adults. *J Am Geriatr Soc.* 2001;49(6):808–23.
4. AGS. American Geriatrics Society Panel on Persistent Pain in Older Persons. The management of persistent pain in older persons. *J Am Geriatr Soc.* 2002;50(Suppl 6):S205–24.

5. Ahmaidi S, Masse-Biron J, Adam B, et al. Effects of interval training at the ventilatory threshold on clinical and cardiorespiratory responses in elderly humans. *Eur J Appl Physiol Occup Physiol.* 1998;78:170–6.
6. Arent SM, Landers DM, Etnier JL. The effects of exercise on mood in older adults: a meta-analytic review. *J Aging Phys Act.* 2000;8:407–30.
7. Asikainen TM, Kukkonen-Harjula K, Miilunpalo S. Exercise for health for early postmenopausal women: a systematic review of randomised controlled trials. *Sports Med.* 2004;34:753–78.
8. Bamman MM, Hill VJ, Adams GR, et al. Gender differences in resistance-training-induced myofiber hypertrophy among older adults. *J Gerontol A Biol Sci Med Sci.* 2003;58(2):108–16.
9. Bandura A. *Self-efficacy: The Exercise of Control.* New York (NY): W.H. Freeman and Company; 1997.
10. Barry BK, Carson RG. Transfer of resistance training to enhance rapid coordinated force production by older adults. *Exp Brain Res.* 2004;159(2):225–38.
11. Bassett DR, Schneider PL, Huntington GE. Physical activity in an Old Order Amish community. *Med Sci Sports Exerc.* 2004;36(1):79–85.
12. Bean J, Herman S, Kiely DK, et al. Weighted stair climbing in mobility-limited older people: a pilot study. *J Am Geriatr Soc.* 2002;50(4):663–70.
13. Bean JF, Herman S, Kiely DK, et al. Increased Velocity Exercise Specific to Task (InVEST) training: a pilot study exploring effects on leg power, balance, and mobility in community-dwelling older women. *J Am Geriatr Soc.* 2004; 52(5):799–804.
14. Belter JG, Carey HV, Garland T Jr. Effects of voluntary exercise and genetic selection for high activity levels on HSP72 expression in house mice. *J Appl Physiol.* 2004;96(4):1270–6.
15. Bermon S, Ferrari P, Bernard P, Altare S, Dolisi C. Responses of total and free insulin-like growth factor-I and insulin-like growth factor binding protein-3 after resistance exercise and training in elderly subjects. *Acta Physiol Scand.* 1999;165(1):51–6.
16. Binder EF, Birge SJ, Spina R, et al. Peak aerobic power is an important component of physical performance in older women. *J Gerontol A Biol Sci Med Sci.* 1999;54:M353–6.
17. Binder EF, Yarasheski KE, Steger-May K, et al. Effects of progressive resistance training on body composition in frail older adults: results of a randomized, controlled trial. *J Gerontol A Biol Sci Med Sci.* 2005;60(11):1425–31.
18. Blair SN, Kampert JB, Kohl HW 3rd, et al. Influences of cardiorespiratory fitness and other precursors on cardiovascular disease and all-cause mortality in men and women. *JAMA.* 1996;276:205–10.
19. Blair SN, Wei M. Sedentary habits, health, and function in older women and men. *Am J Health Promot.* 2000;15(1):1–8.
20. Blumenthal JA, Babyak MA, Moore KA, et al. Effects of exercise training on older patients with major depression. *Arch Intern Med.* 1999;159(19):2349–56.
21. Booth FW, Weeden SH, Tseng BS. Effect of aging on human skeletal muscle and motor function. *Med Sci Sports Exerc.* 1994;26(5):556–60.
22. Borst SE, Vincent KR, Lowenthal DT, Braith RW. Effects of resistance training on insulin-like growth factor and its binding proteins in men and women aged 60 to 85. *J Am Geriatr Soc.* 2002;50(5):884–8.
23. Bosco C, Komi PV. Influence of aging on the mechanical behavior of leg extensor muscles. *Eur J Appl Physiol Occup Physiol.* 1980;45:209–19.
24. Bouchard C, Rankinen T. Individual differences in response to regular physical activity. *Med Sci Sports Exerc.* 2001;33(6 suppl): S446–51; discussion S452–3.
25. Brignole M, Alboni P, Benditt D, et al. Guidelines on management (diagnosis and treatment) of syncope. *Eur Heart J.* 2001;22(15):1256–306.
26. Brosse A, Sheets E, Lett H, Blumenthal J. Exercise and the treatment of clinical depression in adults: recent findings and future directions. *Sports Med.* 2002;32(12):741–60.
27. Brown M, Holloszy JO. Effects of a low intensity exercise program on selected physical performance characteristics of 60- to 71-year olds. *Aging.* 1991;3(2):129–39.
28. Buchner DM, Cress ME, de Lateur BJ, 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 A Biol Sci Med Sci.* 1997;52(4):M218–24.
29. Camacho TC, Roberts RE, Lazarus NB, Kaplan GA, Cohen RD. Physical activity and depression: evidence from the Alameda County Study. *Am J Epidemiol.* 1991;134(2):220–31.
30. Campbell AJ, Robertson MC, Gardner MM, Norton RN, Buchner DM. Falls prevention over 2 years: a randomized controlled trial in women 80 years and older. *Age Ageing.* 1999;28(6):513–8.
31. Campbell AJ, Robertson MC, Gardner MM, Norton RN, Buchner DM. Psychotropic medication withdrawal and a home-based exercise program to prevent falls: a randomized, controlled trial. *J Am Geriatr Soc.* 1999;47(7):850–3.
32. Campbell AJ, Robertson MC, Gardner MM, Norton RN, Tilyard MW, Buchner DM. Randomised controlled trial of a general practice programme of home based exercise to prevent falls in elderly women. *BMJ.* 1997;315(7115):1065–9.
33. Campbell WW, Crim MC, Young VR, Evans WJ. Increased energy requirements and changes in body composition with resistance training in older adults. *Am J Clin Nutr.* 1994; 60(2):167–75.
34. Carmeli E, Reznick AZ, Coleman R, Carmeli V. Muscle strength and mass of lower extremities in relation to functional abilities in elderly adults. *Gerontology.* 2000;46(5):249–57.
35. Chandler JM, Duncan PW, 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.
36. Charette SL, McEvoy L, Pyka G, et al. Muscle hypertrophy response to resistance training in older women. *J Appl Physiol.* 1991;70:1912–6.
37. Chobanian A, Bakris G, Black H, et al. The Seventh Report of the Joint National Committee on Prevention, Detection, Evaluation, and Treatment of High Blood Pressure: the JNC 7 report. *JAMA.* 2003;289(19):2560–72.
38. Coggan AR, Abduljalil AM, Swanson SC, et al. Muscle metabolism during exercise in young and older untrained and endurance-trained men. *J Appl Physiol.* 1993;75:2125–33.
39. Colcombe S, Kramer AF. Fitness effects on the cognitive function of older adults: a meta-analytic study. *Psychol Sci.* 2003;14(2):125–30.
40. Colcombe SJ, Erickson KI, Scalf PE, et al. Aerobic exercise training increases brain volume in aging humans. *J Gerontol A Biol Sci Med Sci.* 2006;61(11):1166–70.
41. Conley KE, Cress ME, Jubrias SA, Esselman PC, Odderson IR. From muscle properties to human performance, using magnetic resonance. *J Gerontol A Biol Sci Med Sci.* 1995;50 Spec No:35–40.
42. Connelly DM, Vandervoort AA. Effects of isokinetic strength training on concentric and eccentric torque development in the ankle dorsiflexors of older adults. *J Gerontol A Biol Sci Med Sci.* 2000;55A(10):B465–B72.
43. Cox JH, Cortright RN, Dohm GL, Houmard JA. Effect of aging on response to exercise training in humans: skeletal muscle GLUT-4 and insulin sensitivity. *J Appl Physiol.* 1999;86:2019–25.

44. Coyle EF, Martin WHr, Sinacore DR, Joyner MJ, Hagberg JM, Holloszy JO. Time course of loss of adaptations after stopping prolonged intense endurance training. *J Appl Physiol.* 1984; 57:1857–64.
45. Craig BW, Brown R, Everhart J. Effects of progressive resistance training on growth hormone and testosterone levels in young and elderly subjects. *Mech Ageing Dev.* 1989;49:159–69.
46. Cress ME, Buchner DM, Prohaska T, et al. Best practices for physical activity programs and behavior counseling in older adult populations. *J Aging Phys Act.* 2005;13(1):61–74.
47. Cress ME, Conley KE, Balding SL, Hansen-Smith F, Konczak J. Functional training: muscle structure, function, and performance in older women. *J Orthop Sports Phys Ther.* 1996;24(1):4–10.
48. Day L, Fildes B, Gordon I, Fitzharris M, Flamer H, Lord S. Randomised factorial trial of falls prevention among older people living in their own homes. *BMJ.* 2002;325(7356):128.
49. DeSouza CA, Shapiro LF, Clevenger CM, et al. Regular aerobic exercise prevents and restores age-related declines in endothelium-dependent vasodilation in healthy men. *Circulation.* 2000; 102:1351–7.
50. DHHS. *2008 Physical Activity Guidelines for Americans.* Rockville (MD): U.S. Department of Health and Human Services; 2008.
51. DHHS. *Physical Activity Guidelines Advisory Committee Report.* Rockville (MD): U.S. Department of Health and Human Services; 2008.
52. DiPietro L, Dziura J, Yeckel CW, Neuffer PD. Exercise and improved insulin sensitivity in older women: evidence of the enduring benefits of higher intensity training. *J Appl Physiol.* 2006;100:142–9.
53. DiPietro L, Williamson DF, Caspersen CJ, Eaker E. The descriptive epidemiology of selected physical activities and body weight among adults trying to lose weight: the Behavioral Risk Factor Surveillance System survey, 1989. *Int J Obes Relat Metab Disord.* 1993;17:69–76.
54. Doody R, Stevens J, Beck C, et al. Practice parameter: management of dementia (an evidence-based review). Report of the Quality Standards Subcommittee of the American Academy of Neurology. *Neurology.* 2001;56(9):1154–66.
55. Douglas PS, O'Toole M. Aging and physical activity determine cardiac structure and function in the older athlete. *J Appl Physiol.* 1992;72:1969–73.
56. Dunn AL, Blair SN, Marcus BH, Carpenter RA, Jaret P. *Active Living Everyday.* Champaign (IL): Human Kinetics; 2001.
57. Earles DR, Judge JO, Gunnarsson OT. Power as a predictor of functional ability in community dwelling older persons. *Med Sci Sports Exerc.* 1997;29(5 suppl):S11.
58. Earles DR, Judge JO, Gunnarsson OT. Velocity training induces power-specific adaptations in highly functioning older adults. *Arch Phys Med Rehabil.* 2001;82:872–8.
59. Ehsani AA, Spina RJ, Peterson LR, et al. Attenuation of cardiovascular adaptations to exercise in frail octogenarians. *J Appl Physiol.* 2003;95:1781–8.
60. Evans WJ. Exercise strategies should be designed to increase muscle power. *J Gerontol A Biol Sci Med Sci.* 2000;55A: M309–M10.
61. Fabre C, Chamari K, Mucci P, Masse-Biron J, Prefaut C. Improvement of cognitive function by mental and/or individualized aerobic training in healthy elderly subjects. *Int J Sports Med.* 2002;23(6):415–21.
62. Fahlman MM, Boardley D, Lambert CP, Flynn MG. Effects of endurance training and resistance training on plasma lipoprotein profiles in elderly women. *J Gerontol A Biol Sci Med Sci.* 2002;57A(2):B54–60.
63. Ferketich AK, Kirby TE, Alway SE. Cardiovascular and muscular adaptations to combined endurance and strength training in elderly women. *Acta Physiol Scand.* 1998;164(3): 259–67.
64. Ferri A, Scaglioni G, Pousson M, Capodaglio P, Van Hoecke J, Narici MV. Strength and power changes of the human plantar flexors and knee extensors in response to resistance training in old age. *Acta Physiol Scand.* 2003;177(1):69–78.
65. Ferrucci L, Bandinelli S, Cavazzini C, et al. Neurological examination findings to predict limitations in mobility and falls in older persons without a history of neurological disease. *Am J Med.* 2004;116(12):807–15.
66. Fiatarone MA, Marks EC, Ryan ND, Meredith CN, Lipsitz LA, Evans WJ. High-intensity strength training in nonagenarians. Effects on skeletal muscle. *JAMA.* 1990;263:3029–34.
67. Fiatarone MA, O'Neill EF, Ryan ND, et al. Exercise training and nutritional supplementation for physical frailty in very elderly people. *N Engl J Med.* 1994;330:1769–75.
68. Fielding RA, LeBrasseur NK, Cuoco A, Bean J, Mizer K, Fiatarone Singh MA. High-velocity resistance training increases skeletal muscle peak power in older women. *J Am Geriatr Soc.* 2002;50:655–62.
69. FitzGerald SJ, Barlow CE, Kampert JB, Morrow JR, Jackson AW, Blair SN. Muscular fitness and all-cause mortality: prospective observations. *J Phys Act Health.* 2004;1(1):7–18.
70. Fletcher G, Balady G, Amsterdam E, et al. Exercise standards for testing and training: a statement for healthcare professionals from the American Heart Association. *Circulation.* 2001;104 (14):1694–740.
71. Foldvari M, Clark M, Laviolette LC, et al. Association of muscle power with functional status in community-dwelling elderly women. *J Gerontol A Biol Sci Med Sci.* 2000;55A: M192–9.
72. Folkens CH, Sime WE. Physical fitness training and mental health. *Am Psychol.* 1981;36(4):373–89.
73. Frontera WR, Meredith CN, O'Reilly KP, Knuttgen HG, Evans WJ. Strength conditioning in older men: skeletal muscle hypertrophy and improved function. *J Appl Physiol.* 1988;64: 1038–44.
74. Gillespie LD, Gillespie WJ, Robertson MC, Lamb SE, Cumming RG, Rowe BH. Interventions for preventing falls in elderly people. *Cochrane Database Syst Rev.* 2003;(4): CD000340.
75. Going S, Lohman T, Houtkooper L, et al. Effects of exercise on bone mineral density in calcium-replete postmenopausal women with and without hormone replacement therapy. *Osteoporos Int.* 2003;14(8):637–43.
76. Going S, Williams D, Lohman T. Aging and body composition: biological changes and methodological issues. *Exerc Sport Sci Rev.* 1995;23:411–58.
77. Goldspink D. Ageing and activity: their effects on the functional reserve capacities of the heart and vascular smooth and skeletal muscles. *Ergonomics.* 2005;48:1334–51.
78. Goodpaster BH, Costill DL, Trappe SW, et al. The relationship of sustained exercise training and bone mineral density in aging male runners. *Scand J Med Sci Sports.* 1996;6:216–21.
79. Gordon N, Gulanic M, Costa F, et al. Physical activity and exercise recommendations for stroke survivors: an American Heart Association scientific statement from the Council on Clinical Cardiology, Subcommittee on Exercise, Cardiac Rehabilitation, and Prevention; the Council on Cardiovascular Nursing; the Council on Nutrition, Physical Activity, and Metabolism; and the Stroke Council. *Circulation.* 2004;109 (16):2031–41.
80. Greendale GA, Salem GJ, Young JT, et al. A randomized trial of weighted vest use in ambulatory older adults: strength, performance, and quality of life outcomes. *J Am Geriatr Soc.* 2000; 48(3):305–11.
81. Greist JH, Klein MH, Eischens RR, Faris J, Gurman AS, Morgan WP. Running as treatment for depression. *Compr Psychiatry.* 1979;20(1):41–54.

82. Grimby G, Aniansson A, Hedberg M, Henning GB, Grangard U, Kvist H. Training can improve muscle strength and endurance in 78- to 84-yr-old men. *J Appl Physiol*. 1992;73(6):2517-23.
83. Hagberg JM, Allen WK, Seals DR, Hurley BF, Ehsani AA, Holloszy JO. A hemodynamic comparison of young and older endurance athletes during exercise. *J Appl Physiol*. 1985;58:2041-6.
84. Hagberg JM, Graves JE, Limacher M, et al. Cardiovascular responses of 70- to 79-yr-old men and women to exercise training. *J Appl Physiol*. 1989;66:2589-94.
85. Hagen K, Hilde G, Jamtvedt G, Winnem M. The Cochrane review of advice to stay active as a single treatment for low back pain and sciatica. *Spine*. 2002;27(16):1736-41.
86. Hagerman FC, Walsh SJ, Staron RS, et al. Effects of high-intensity resistance training on untrained older men: I. Strength, cardiovascular, and metabolic responses. *J Gerontol A Biol Sci Med Sci*. 2000;55A(7):B336-46.
87. Häkkinen K, Pakarinen A, Kraemer WJ, Newton RU, Alen M. Basal concentrations and acute responses of serum hormones and strength development during heavy resistance training in middle-aged and elderly men and women. *J Gerontol A Biol Sci Med Sci*. 2000;55A(2):B95-105.
88. Häkkinen K, Häkkinen A. Muscle cross-sectional area, force production and relaxation characteristics in women at different ages. *Eur J Appl Physiol Occup Physiol*. 1991;62:410-4.
89. Häkkinen K, Kraemer WJ, Newton RU, Alen M. Changes in electromyographic activity, muscle fibre and force production characteristics during heavy resistance/power strength training in middle-aged and older men and women. *Acta Physiol Scand*. 2001;171:51-62.
90. Häkkinen K, Alen M, Kallinen M, Newton RU, Kraemer WJ. Neuromuscular adaptation during prolonged strength training, detraining and re-strength-training in middle-aged and elderly people. *Eur J Appl Physiol*. 2000;83(1):51-62.
91. Häkkinen K, Newton RU, Gordon SE, et al. Changes in muscle morphology, electromyographic activity, and force production characteristics during progressive strength training in young and older men. *J Gerontol A Biol Sci Med Sci*. 1998;53(6):B415-23.
92. Häkkinen K, Pakarinen A, Newton RU, Kraemer WJ. Acute hormone responses to heavy resistance lower and upper extremity exercise in young versus old men. *Eur J Appl Physiol Occup Physiol*. 1998;77(4):312-9.
93. Häkkinen K, Kraemer WJ, Kallinen M, et al. Bilateral and unilateral neuromuscular function and muscle cross-sectional area in middle-aged and elderly men and women. *J Gerontol A Biol Sci Med Sci*. 1996;51A:B21-9.
94. Hameed M, Lange KH, Andersen JL, et al. The effect of recombinant human growth hormone and resistance training on IGF-I mRNA expression in the muscles of elderly men. *J Physiol*. 2004;555(Pt 1):231-40.
95. Hameed M, Orrell RW, Cobbold M, Goldspink G, Harridge SD. Expression of IGF-I splice variants in young and old human skeletal muscle after high resistance exercise. *J Physiol*. 2003;547(Pt 1):247-54.
96. Henwood TR, Taaffe DR. Improved physical performance in older adults undertaking a short-term programme of high-velocity resistance training. *Gerontology*. 2005;51(2):108-15.
97. Holloszy J. The biology of aging. *Mayo Clin Proc*. 2000;75(Suppl):S3-8; discussion S8-9.
98. Holloszy JO, Kohrt WM. Sect. 11. Chapt. 24: Exercise. In: *Handbook of Physiology. Aging*. Bethesda (MD): American Physiological Society; 1995. p. 633-66.
99. Holviala JH, Sallinen JM, Kraemer WJ, Alen MJ, Häkkinen KK. Effects of strength training on muscle strength characteristics, functional capabilities, and balance in middle-aged and older women. *J Strength Cond Res*. 2006;20(2):336-44.
100. Huang G, Gibson CA, Tran ZV, Osness WH. Controlled endurance exercise training and $\dot{V}O_{2\max}$ changes in older adults: a meta-analysis. *Prev Cardiol*. 2005;8:217-25.
101. Huang G, Shi X, Davis-Brezette JA, Osness WH. Resting heart rate changes after endurance training in older adults: a meta-analysis. *Med Sci Sports Exerc*. 2005;37(8):1381-6.
102. Hunter GR, Bryan DR, Wetzstein CJ, Zuckerman PA, Bamman MM. Resistance training and intra-abdominal adipose tissue in older men and women. *Med Sci Sports Exerc*. 2002;34(6):1023-8.
103. Hunter GR, McCarthy JP, Bamman MM. Effects of resistance training on older adults. *Sports Med*. 2004;34(5):329-48.
104. Hunter GR, Treuth MS, Weinsien RL, et al. The effects of strength conditioning on older women's ability to perform daily tasks. *J Am Geriatr Soc*. 1995;43(7):756-60.
105. Hunter GR, Wetzstein CJ, Fields DA, Brown A, Bamman MM. Resistance training increases total energy expenditure and free-living physical activity in older adults. *J Appl Physiol*. 2000;89:977-84.
106. Hunter GR, Wetzstein CJ, McLafferty CL, Zuckerman PA, Landers KA, Bamman MM. High-resistance versus variable-resistance training in older adults. *Med Sci Sports Exerc*. 2001;33(10):1759-64.
107. Hurley BF, Hagberg JM. Optimizing health in older persons: aerobic or strength training? *Exerc Sport Sci Rev*. 1998;26:61-89.
108. Ibanez J, Izquierdo M, Arguelles I, et al. Twice-weekly progressive resistance training decreases abdominal fat and improves insulin sensitivity in older men with type 2 diabetes. *Diabetes Care*. 2005;28(3):662-7.
109. Ivey FM, Roth SM, Ferrell RE, et al. Effects of age, gender, and myostatin genotype on the hypertrophic response to heavy resistance strength training. *J Gerontol A Biol Sci Med Sci*. 2000;55:M641-8.
110. Ivey FM, Tracy BL, Lemmer JT, et al. Effects of strength training and detraining on muscle quality: age and gender comparisons. *J Gerontol A Biol Sci Med Sci*. 2000;55(3):B152-7.
111. Izquierdo M, Ibanez J, Gorostiaga E, et al. Maximal strength and power characteristics in isometric and dynamic actions of the upper and lower extremities in middle-aged and older men. *Acta Physiol Scand*. 1999;167:57-68.
112. Izquierdo M, Häkkinen K, Ibanez J, et al. Effects of strength training on muscle power and serum hormones in middle-aged and older men. *J Appl Physiol*. 2001;90(4):1497-507.
113. Janssen I, Ross R. Linking age-related changes in skeletal muscle mass and composition with metabolism and disease. *J Nutr Health Aging*. 2005;9:408-19.
114. Joseph LJO, Davey SL, Evans WJ, Campbell WW. Differential effect of resistance training on the body composition and lipoprotein—lipid profile in older men and women. *Metabolism*. 1999;48(11):1474-80.
115. Jozsi AC, Campbell WW, Joseph L, Davey SL, Evans WJ. Changes in power with resistance training in older and younger men and women. *J Gerontol A Biol Sci Med Sci*. 1999;54A:M591-6.
116. Jubrias SA, Esselman PC, Price LB, Cress ME, Conley KE. Large energetic adaptations of elderly muscle to resistance and endurance training. *J Appl Physiol*. 2001;90:1663-70.
117. Judge JO, Whipple RH, Wolfson LI. Effects of resistive and balance exercises on isokinetic strength in older persons. *J Am Geriatr Soc*. 1994;42(9):937-46.
118. Judge JO, Underwood M, Gennosa T. Exercise to improve gait velocity in older persons. *Arch Phys Med Rehabil*. 1993;74(4):400-6.
119. Kallman DA, Plato CC, Tobin JD. The role of muscle loss in the age-related decline of grip strength: cross-sectional and longitudinal perspectives. *J Gerontol*. 1990;45:M82-8.

120. Kasch FW, Boyer JL, Schmidt PK, et al. Ageing of the cardiovascular system during 33 years of aerobic exercise. *Age Ageing*. 1999;28:531–6.
121. Katsanos C. Prescribing aerobic exercise for the regulation of postprandial lipid metabolism : current research and recommendations. *Sports Med*. 2006;36:547–60.
122. Katzmarzyk PT, Craig CL. Musculoskeletal fitness and risk of mortality. *Med Sci Sports Exerc*. 2002;34(5):740–4.
123. Kay SJ, Fiatarone Singh MA. The influence of physical activity on abdominal fat: a systematic review of the literature. *Obes Rev*. 2006;7:183–200.
124. Kelley GA. Exercise and regional bone mineral density in postmenopausal women: a meta-analytic review of randomized trials. *Am J Phys Med Rehabil*. 1998;77(1):76–87.
125. Kelley GA, Kelley KS, Tran ZV. Exercise and bone mineral density in men: a meta-analysis. *J Appl Physiol*. 2000;88:1730–6.
126. Kenney WL, Munce TA. Invited review: aging and human temperature regulation. *J Appl Physiol*. 2003;95:2598–603.
127. Keysor JJ. Does late-life physical activity or exercise prevent or minimize disablement? A critical review of the scientific evidence. *Am J Prev Med*. 2003;25(3 Suppl 2):129–36.
128. King AC, Taylor CB, Haskell WL. Effects of differing intensities and formats of 12 months of exercise training on psychological outcomes in older adults. *Health Psychol*. 1993;12(4):292–300.
129. Kirwan JP, Kohrt WM, Wojta DM, Bourey RE, Holloszy JO. Endurance exercise training reduces glucose-stimulated insulin levels in 60- to 70-year-old men and women. *J Gerontol*. 1993;48:M84–90.
130. Klein CS, Marsh GD, Petrella RJ, Rice CL. Muscle fiber number in the biceps brachii muscle of young and old men. *Muscle Nerve*. 2003;28(1):62–8.
131. Klitgaard H, Mantoni M, Schiaffino S, et al. Function, morphology and protein expression of ageing skeletal muscle: a cross-sectional study of elderly men with different training backgrounds. *Acta Physiol Scand*. 1990;140:41–54.
132. Kohrt WM, Bloomfield SA, Little KD, Nelson ME, Yingling VR. American College of Sports Medicine. Position Stand. Physical activity and bone health. *Med Sci Sports Exerc*. 2004;36(11):1985–96.
133. Kraemer WJ, Häkkinen K, Newton RU, et al. Effects of heavy-resistance training on hormonal response patterns in younger vs. older men. *J Appl Physiol*. 1999;87(3):982–92.
134. Kramer AF, Erickson KI, Colcombe SJ. Exercise, cognition, and the aging brain. *J Appl Physiol*. 2006;101(4):1237–42.
135. Kramer AF, Hahn S, Cohen NJ, et al. Ageing, fitness and neurocognitive function. *Nature*. 1999;400(6743):418–9.
136. Laidlaw DH, Kornatz KW, Keen DA, Suzuki S, Enoka RM. Strength training improves the steadiness of slow lengthening contractions performed by old adults. *J Appl Physiol*. 1999;87(5):1786–95.
137. Lakatta EG, Levy D. Arterial and cardiac aging: major shareholders in cardiovascular disease enterprises: Part I: Aging arteries: a “set up” for vascular disease. *Circulation*. 2003;107:139–46.
138. Laurin D, Verreault R, Lindsay J, MacPherson K, Rockwood K. Physical activity and risk of cognitive impairment and dementia in elderly persons. *Arch Neurol*. 2001;58(3):498–504.
139. Lemmer JT, Hurlbut DE, Martel GF, et al. Age and gender responses to strength training and detraining. *Med Sci Sports Exerc*. 2000;32(8):1505–12.
140. Lexell J, Downham DY, Larsson Y, Bruhn E, Morsing B. Heavy-resistance training in older Scandinavian men and women: short- and long-term effects on arm and leg muscles. *Scand J Med Sci Sports*. 1995;5(6):329–41.
141. Li F, Harmer P, Fisher KJ, et al. Tai chi and fall reductions in older adults: a randomized controlled trial. *J Gerontol A Biol Sci Med Sci*. 2005;60(2):187–94.
142. Locke GR, Pemberton J, Phillips S. American Gastroenterological Association Medical Position Statement: guidelines on constipation. *Gastroenterology*. 2000;119(6):1761–6.
143. Lyons DM, Yang C, Eliez S, Reiss AL, Schatzberg AF. Cognitive correlates of white matter growth and stress hormones in female squirrel monkey adults. *J Neurosci*. 2004;24(14):3655–62.
144. Macaluso A, De Vito G, Felici F, Nimmo MA. Electromyogram changes during sustained contraction after resistance training in women in their 3rd and 8th decades. *Eur J Appl Physiol*. 2000;82(5-6):418–24.
145. Makrides L, Heigenhauser GJ, Jones NL. High-intensity endurance training in 20- to 30- and 60- to 70-yr-old healthy men. *J Appl Physiol*. 1990;69:1792–8.
146. Malbut KE, Dinan S, Young A. Aerobic training in the ‘oldest old’: the effect of 24 weeks of training. *Age Ageing*. 2002;31:255–60.
147. Marquis S, Moore MM, Howieson DB, et al. Independent predictors of cognitive decline in healthy elderly persons. *Arch Neurol*. 2002;59(4):601–6.
148. Martel GF, Roth SM, Ivey FM, et al. Age and sex affect human muscle fibre adaptations to heavy-resistance strength training. *Exp Physiol*. 2006;91(2):457–64.
149. Martin WH, Kohrt WM, Malley MT, Korte E, Stoltz S. Exercise training enhances leg vasodilatory capacity of 65-yr-old men and women. *J Appl Physiol*. 1990;69:1804–9.
150. Martinsen EW, Hoffart A, Solberg O. Comparing aerobic with nonaerobic forms of exercise in the treatment of clinical depression: a randomized trial. *Compr Psychiatry*. 1989;30(4):324–31.
151. Martinsen EW, Medhus A, Sandvik L. Effects of aerobic exercise on depression: a controlled study. *Br Med J (Clin Res Ed)*. 1985;291(6488):109.
152. Masoro E. *Handbook of Physiology Section 11*. In: Masoro E, editor. New York (NY): Oxford University Press; 1995. p. 3–21.
153. Mather AS, Rodriguez C, Guthrie MF, McHarg AM, Reid IC, McMurdo ME. Effects of exercise on depressive symptoms in older adults with poorly responsive depressive disorder: randomized controlled trial. *Br J Psychiatry*. 2002;180:411–5.
154. McAuley E, Blissmer B, Marquez DX, Jerome GJ, Kramer AF, Katula J. Social relations, physical activity, and well-being in older adults. *Prev Med*. 2000;31(5):608–17.
155. McAuley E, Katula J. Physical activity interventions in the elderly: influence on physical health and psychological function. In: Schulz MPLR, Maddox G, editors. *Annual Review of Gerontology and Geriatrics*. New York (NY): Springer Publishing; 1998. p. 115–54.
156. McAuley E, Rudolph D. Physical activity, aging, and psychological well-being. *J Aging Phys Act*. 1995;3(1):67–98.
157. McDermott M, Liu K, Ferrucci L, et al. Physical performance in peripheral arterial disease: a slower rate of decline in patients who walk more. *Ann Intern Med*. 2006;144(1):10–20.
158. Meijer EP, Westertep KR, Verstappen FT. Effect of exercise training on physical activity and substrate utilization in the elderly. *Int J Sports Med*. 2000;21(7):499–504.
159. Metter EJ, Conwit R, Tobin J, Fozard JL. Age-associated loss of power and strength in the upper extremities in women and men. *J Gerontol A Biol Sci Med Sci*. 1997;52A:B267–76.
160. Metter EJ, Talbot LA, Schrage M, Conwit RA. Arm-cranking muscle power and arm isometric muscle strength are independent predictors of all-cause mortality in men. *J Appl Physiol*. 2004;96:814–21.
161. Michel BA, Lane NE, Bjorkengren A, Bloch DA, Fries JF. Impact of running on lumbar bone density: a 5-year longitudinal study. *J Rheumatol*. 1992;19:1759–63.
162. Miszko TA, Cress ME, Slade JM, Covey CJ, Agrawal SK, Doerr CE. Effect of strength and power training on physical function in community-dwelling older adults. *J Gerontol A Biol Sci Med Sci*. 2003;58(2):171–5.

163. Moritani T, deVries HA. Potential for gross muscle hypertrophy in older men. *J Gerontol.* 1980;35(5):672–82.
164. Mussolino ME, Looker AC, Orwoll ES. Jogging and bone mineral density in men: results from NHANES III. *Am J Public Health.* 2001;91:1056–9.
165. NCEP. Third Report of the National Cholesterol Education Program (NCEP) Expert Panel on Detection, Evaluation, and Treatment of High Blood Cholesterol in Adults (Adult Treatment Panel III): NIH Publication No. 01-3670. 2001.
166. NCHS. DATA 2010. *National Center for Health Statistics.* 2008.
167. Nelson ME, Rejeski WJ, Blair SN, et al. Physical activity and public health in older adults: recommendation from the American College of Sports Medicine and the American Heart Association. *Circulation.* 2007;116(9):1094–105.
168. Netz Y, Wu MJ, Becker BJ, Tenenbaum W. Physical activity and psychological well-being in advanced age: a meta-analysis of intervention studies. *Psychol Aging.* 2005;20(2):272–84.
169. Newton RU, Hakkinen K, Hakkinen A, McCormick M, Volek J, Kraemer WJ. Mixed-methods resistance training increases power and strength of young and older men. *Med Sci Sports Exerc.* 2002;34(8):1367–75.
170. NHLBI. *Global Initiative for Chronic Obstructive Lung Disease (GOLD). Global Strategy for the Diagnosis, Management, and Prevention of Chronic Obstructive Pulmonary Disease.* In: National Heart, and Blood Institute, editor. Bethesda (MD): NHLBI; 2001.
171. Norton R, Galgali G, Campbell AJ, et al. Is physical activity protective against hip fracture in frail older people? *Age Ageing.* 2001;30(3):262–4.
172. Ochala J, Lambert D, Van Hoecke J, Pousson M. Effect of strength training on musculotendinous stiffness in elderly individuals. *Eur J Appl Physiol.* 2005;94(1–2):126–33.
173. Ogawa T, Spina RJ, Martin WH, et al. Effects of aging, sex, and physical training on cardiovascular responses to exercise. *Circulation.* 1992;86:494–503.
174. Okazaki K, Iwasaki K, Prasad A, et al. Dose–response relationship of endurance training for autonomic circulatory control in healthy seniors. *J Appl Physiol.* 2005;99:1041–9.
175. Olshansky SJ, Hayflick L, Carnes BA. Position statement on human aging. *J Gerontol A Biol Sci Med Sci.* 2002;57(8):B292–7.
176. Osthega Y, Harris TB, Hirsch R, Parsons VL, Kington R. The prevalence of functional limitations and disability in older persons in the US: data from the National Health and Nutrition Examination Survey III. *J Am Geriatr Soc.* 2000;48:1132–5.
177. Oswald WD, Rupprecht R, Gunzelmann T, Tritt K. The SIMA-project: effects of 1 year cognitive and psychomotor training on cognitive abilities of the elderly. *Behav Brain Res.* 1996;78(1):67–72.
178. Parkhouse WS, Coupland DC, Li C, Vanderhoek KJ. IGF-1 bioavailability is increased by resistance training in older women with low bone mineral density. *Mech Ageing Dev.* 2000;113(2):75–83.
179. Paterson D. Physical activity, fitness, and gender in relation to morbidity, survival, quality of life, and independence in older age. In: Shephard R, editor. *Gender, Physical Activity, and Aging.* Boca Raton (FL): CRC Press; 2002. p. 99–120.
180. Paterson DH, Govindasamy D, Vidmar M, Cunningham DA, Koval JJ. Longitudinal study of determinants of dependence in an elderly population. *J Am Geriatr Soc.* 2004;52(10):1632–8.
181. Patla AE, Frank JS, Winter DA. Balance control in the elderly: implications for clinical assessment and rehabilitation. *Can J Public Health.* 1992;83(Suppl 2):S29–33.
182. Pavot W, Diener E, Colvin CR, Sandvik E. Further validation of the Satisfaction with Life Scale: evidence for the cross-method convergence of well-being measures. *J Pers Assess.* 1991;57(1):149–61.
183. Pescatello L, Franklin B, Fagard R, Farquhar W, Kelley G, Ray C. American College of Sports Medicine. Position Stand. Exercise and hypertension. *Med Sci Sports Exerc.* 2004;36(3):533–53.
184. Petrella RJ, Cunningham DA, Paterson DH. Effects of 5-day exercise training in elderly subjects on resting left ventricular diastolic function and $\dot{V}O_{2\max}$. *Can J Appl Physiol.* 1997;22:37–47.
185. Pollock M, Franklin B, Balady G, et al. American Heart Association Science Advisory. Resistance exercise in individuals with and without cardiovascular disease: benefits, rationale, safety, and prescription: an advisory from the Committee on Exercise, Rehabilitation, and Prevention, Council on Clinical Cardiology, American Heart Association; Position paper endorsed by the American College of Sports Medicine. *Circulation.* 2000;101(7):828–33.
186. Porter NM, Landfield PW. Stress hormones and brain aging: adding injury to insult? *Nat Neurosci.* 1998;1(1):3–4.
187. Proctor DN. Longitudinal changes in physical functional performance among the oldest-old: insight from a study of Swedish twins. *Aging Clin Exp Res.* 2006;18:517–30.
188. Proctor DN, Sinning WE, Walro JM, Sieck GC, Lemon PW. Oxidative capacity of human muscle fiber types: effects of age and training status. *J Appl Physiol.* 1995;78:2033–8.
189. Proctor DN, Dietz NM, Eickhoff TJ, et al. Reduced leg blood flow during dynamic exercise in older endurance-trained men. *J Appl Physiol.* 1998;85:68–75.
190. Racette SB, Evans EM, Weiss EP, Hagberg JM, Holloszy JO. Abdominal adiposity is a stronger predictor of insulin resistance than fitness among 50–95 year olds. *Diabetes Care.* 2006;29:673–8.
191. Rafferty AP, Reeves MJ, McGee HB, Pivarnik JM. Physical activity patterns among walkers and compliance with public health recommendations. *Med Sci Sports Exerc.* 2002;34(8):1255–61.
192. Rantanen T, Guralnik JM, Foley D, et al. Midlife hand grip strength as a predictor of old age disability. *JAMA.* 1999;281:558–60.
193. Reeves ND, Maganaris CN, Narici MV. Effect of strength training on human patella tendon mechanical properties of older individuals. *J Physiol.* 2003;548(Pt 3):971–81.
194. Reeves ND, Narici MV, Maganaris CN. Effect of resistance training on skeletal muscle-specific force in elderly humans. *J Appl Physiol.* 2004;96(3):885–92.
195. Reeves ND, Narici MV, Maganaris CN. In vivo human muscle structure and function: adaptations to resistance training in old age. *Exp Physiol.* 2004;89(6):675–89.
196. Rejeski WJ, Mihalko SL. Physical activity and quality of life in older adults. *J Gerontol A Biol Sci Med Sci.* 2001;56 Spec No 2:23–35.
197. Remme W, Swedberg K. Guidelines for the diagnosis and treatment of chronic heart failure. *Eur Heart J.* 2001;22(17):1527–60.
198. Rhodes EC, Martin AD, Taunton JE, Donnelly M, Warren J, Elliot J. Effects of one year of resistance training on the relation between muscular strength and bone density in elderly women. *Br J Sports Med.* 2000;34(1):18–22.
199. Rico-Sanz J, Rankinen T, Joannis DR, et al. Familial resemblance for muscle phenotypes in the HERITAGE Family Study. *Med Sci Sports Exerc.* 2003;35(8):1360–6.
200. Rider RA, Daly J. Effects of flexibility training on enhancing spinal mobility in older women. *J Sports Med Phys Fitness.* 1991;31:213–7.
201. Rogers MA, King DS, Hagberg JM, Ehsani AA, Holloszy JO. Effect of 10 days of physical inactivity on glucose tolerance in master athletes. *J Appl Physiol.* 1990;68:1833–7.
202. Rose DJ. Promoting functional independence in older adults at risk for falls. *J Aging Phys Act.* 2002;10:1–19.
203. Roth SM, Ivey FM, Martel GF, et al. Muscle size responses to

- strength training in young and older men and women. *J Am Geriatr Soc.* 2001;49:1428–33.
204. Said CM, Goldie PA, Patla AE, Culham E, Sparrow WA, Morris ME. Balance during obstacle crossing following stroke. *Gait Posture.* 2008;27(1):23–30.
 205. Salem GJ, Wang MY, Young JT, Marion M, Greendale GA. Knee strength and lower- and higher-intensity functional performance in older adults. *Med Sci Sports Exerc.* 2000;32(10):1679–84.
 206. Saltin B. The aging endurance athlete. In: Sutton J, Brock RM, editors. *Sports Medicine for the Mature Athlete.* Indianapolis (IN): Benchmark; 1986. p. 59–80.
 207. Samaras K, Kelly PJ, Chiano MN, Spector TD, Campbell LV. Genetic and environmental influences on total-body and central abdominal fat: the effect of physical activity in female twins. *Ann Intern Med.* 1999;130:873–82.
 208. Schlicht J, Camaione DN, Owen SV. Effect of intense strength training on standing balance, walking speed, and sit-to-stand performance in older adults. *J Gerontol A Biol Sci Med Sci.* 2001;56(5):M281–6.
 209. Schoenborn CA, Adams PF, Barnes PM, Vickerie JL, Schiller JS. Health behaviors of adults: United States, 1999–2001. *Vital Health Stat 10.* 2004;(219):1–79.
 210. Schulman S, Fleg J, Goldberg A, et al. Continuum of cardiovascular performance across a broad range of fitness levels in healthy older men. *Circulation.* 1996;94(3):359–67.
 211. Seals DR, Hurley BF, Schultz J, Hagberg JM. Endurance training in older men and women II. Blood lactate response to submaximal exercise. *J Appl Physiol.* 1984;57:1030–3.
 212. Seals DR, Hagberg JM, Hurley BF, Ehsani AA, Holloszy JO. Endurance training in older men and women. I. Cardiovascular responses to exercise. *J Appl Physiol.* 1984;57:1024–9.
 213. Seals DR, Taylor JA, Ng AV, Esler MD. Exercise and aging: autonomic control of the circulation. *Med Sci Sports Exerc.* 1994;26(5):568–76.
 214. Seeman TE, Berkman LF, Charpentier PA, Blazer DG, Albert MS, Tinetti ME. Behavioral and psychosocial predictors of physical performance: MacArthur studies of successful aging. *J Gerontol A Biol Sci Med Sci.* 1995;50:M177–83.
 215. Sharman MJ, Newton RU, Triplett-McBride T, et al. Changes in myosin heavy chain composition with heavy resistance training in 60- to 75-year-old men and women. *Eur J Appl Physiol.* 2001;84(1–2):127–32.
 216. Shchoenborn C, Adams PF, Barnes PM, Vickerie JL, Schiller JS. 1991–2001. In: VH Statistics, editor. *Health Behaviors of Adults: United States.* Washington (DC): National Center for Health Statistics; 2004. p. 39–54.
 217. Shephard R. *Aging, Physical Activity, and Health.* Champaign (IL): Human Kinetics; 1997.
 218. Short KR, Vittone JL, Bigelow ML, et al. Impact of aerobic exercise training on age-related changes in insulin sensitivity and muscle oxidative capacity. *Diabetes Care.* 2003;52:1888–96.
 219. Sial S, Coggan AR, Hickner RC, Klein S. Training-induced alterations in fat and carbohydrate metabolism during exercise in elderly subjects. *Am J Physiol.* 1998;274:E785–90.
 220. Sigal R, Kenny G, Wasserman D, Castaneda-Sceppa C. Physical activity/exercise and type 2 diabetes. *Diabetes Care.* 2004; 27(10):2518–39.
 221. Simonsick EM, Lafferty ME, Phillips CL, et al. Risk due to inactivity in physically capable older adults. *Am J Public Health.* 1993;83(10):1443–50.
 222. Singh M. Exercise and aging. *Clin Geriatr Med.* 2004;20:201–21.
 223. Singh N, Clements KM, Fiatarone MA. A randomized controlled trial of the effect of exercise on sleep. *Sleep.* 1997;20(2): 95–101.
 224. Singh NA, Clements KM, Fiatarone MA. A randomized controlled trial of progressive resistance training in depressed elders. *J Gerontol A Biol Sci Med Sci.* 1997;52(1):M27–35.
 225. Singh NA, Clements KM, Singh MA. The efficacy of exercise as a long-term antidepressant in elderly subjects: a randomized, controlled trial. *J Gerontol A Biol Sci Med Sci.* 2001;56(8): M497–504.
 226. Sipila S, Multanen J, Kallinen M, Era P, Suominen H. Effects of strength and endurance training on isometric muscle strength and walking speed in elderly women. *Acta Physiol Scand.* 1996; 156(4):457–64.
 227. Skelton DA, Young A, Greig CA, Malbut KE. 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.
 228. Spina R. Cardiovascular adaptations to endurance exercise training in older men and women. *Exerc Sport Sci Rev.* 1999;27:317–32.
 229. Spina RJ, Turner MJ, Ehsani AA. Exercise training enhances cardiac function in response to an afterload stress in older men. *Am J Physiol.* 1997;272:H995–1000.
 230. Spirduso WW, Cronin DL. Exercise dose–response effects on quality of life and independent living in older adults. *Med Sci Sports Exerc.* 2001;33(6 suppl):S598–608; discussion S609–10.
 231. Spirduso WW, Francis KL, MacRae PG. *Physical Dimensions of Aging.* Champaign (IL): Human Kinetics; 2005.
 232. Stewart K, Hiatt W, Regensteiner J, Hirsch A. Exercise training for claudication. *N Engl J Med.* 2002;347(24):1941–51.
 233. Stewart KJ, Bacher AC, Hees PS, Tayback M, Ouyang P, Jan de Beur S. Exercise effects on bone mineral density relationships to changes in fitness and fatness. *Am J Prev Med.* 2005;28(5):453–60.
 234. Stratton J, Levy W, Cerqueira M, Schwartz R, Abrass I. Cardiovascular responses to exercise: effects of aging and exercise training in healthy men. *Circulation.* 1994;89:1648–55.
 235. Sugawara J, Miyachi M, Moreau KL, Dinunno FA, DeSouza CA, Tanaka H. Age-related reductions in appendicular skeletal muscle mass: association with habitual aerobic exercise status. *Clin Physiol Funct Imaging.* 2002;22:169–72.
 236. Suominen H. Muscle training for bone strength. *Aging Clin Exp Res.* 2006;18:85–93.
 237. Taaffe DR, Pruitt L, Reim J, Butterfield G, Marcus R. Effect of sustained resistance training on basal metabolic rate in older women. *J Am Geriatr Soc.* 1995;43(5):465–71.
 238. Tabbarah M, Crimmins EM, Seeman TE. The relationship between cognitive and physical performance: MacArthur Studies of Successful Aging. *J Gerontol A Biol Sci Med Sci.* 2002;57(4): M228–35.
 239. Tanaka H, Dinunno FA, Monahan KD, Clevenger CM, DeSouza CA, Seals DR. Aging, habitual exercise, and dynamic arterial compliance. *Circulation.* 2000;102:1270–5.
 240. Taylor AH, Cable NT, Faulkner G, Hillsdon M, Narici M, Van Der Bij AK. Physical activity and older adults: a review of health benefits and the effectiveness of interventions. *J Sports Sci.* 2004;22(8):703–25.
 241. Thompson P, Buchner D, Pina I. Exercise and physical activity in the prevention and treatment of atherosclerotic cardiovascular disease: a statement from the Council on Clinical Cardiology (Subcommittee on Exercise, Rehabilitation, and Prevention) and the Council on Nutrition, Physical Activity, and Metabolism (Subcommittee on Physical Activity). *Circulation.* 2003;107(24): 3109–16.
 242. Thompson PD, Crouse SF, Goodpaster B, Kelley D, Moyna N, Pescatello L. The acute versus the chronic response to exercise. *Med Sci Sports Exerc.* 2001;33(6 suppl):S438–45; discussion S452–3.
 243. Tinetti ME, Baker DI, McAvay G, et al. A multifactorial intervention to reduce the risk of falling among elderly people living in the community. *N Engl J Med.* 1994;331(13):821–7.
 244. Toth MJ, Beckett T, Poehlman ET. Physical activity and the progressive change in body composition with aging: current evidence and research issues. *Med Sci Sports Exerc.* 1999;31(11 suppl): S590–6.

245. Toth MJ, Gardner AW, Ades PA, Poehlman ET. Contribution of body composition and physical activity to age-related decline in peak $\dot{V}O_2$ in men and women. *J Appl Physiol*. 1994;77:647–52.
246. Tracy BL, Ivey FM, Hurlbut D, et al. Muscle quality: II. Effects of strength training in 65- to 75-yr-old men and women. *J Appl Physiol*. 1999;86(1):195–201.
247. Trappe SW, Costill DL, Vukovich MD, Jones J, Melham T. Aging among elite distance runners: a 22-yr longitudinal study. *J Appl Physiol*. 1996;80:285–90.
248. Treuth MS, Hunter GR, Kekes-Szabo T, Weinsier RL, Goran MI, Berland L. Reduction in intra-abdominal adipose tissue after strength training in older women. *J Appl Physiol*. 1995;78(4):1425–31.
249. Treuth MS, Hunter GR, Weinsier RL, Kell SH. Energy expenditure and substrate utilization in older women after strength training: 24-h calorimeter results. *J Appl Physiol*. 1995;78(6):2140–6.
250. Tsutsumi T, Don BM, Zaichkowsky LD, Takenaka K, Oka K, Ohno T. Comparison of high and moderate intensity of strength training on mood and anxiety in older adults. *Percept Mot Skills*. 1998;87(3 Pt 1):1003–11.
251. USDHHS. *Bone Health and Osteoporosis: A Report of the Surgeon General*. In: OotSG Department of Health and Human Services, editor. Rockville (MD): USDHHS; 2004.
252. USPSTF. Screening for obesity in adults: recommendations and rationale. *Ann Intern Med*. 2003;139(11):930–2.
253. Vandervoort A. Aging of the human neuromuscular system. *Muscle Nerve*. 2002;25:17–25.
254. Vincent KR, Braith RW. Resistance exercise and bone turnover in elderly men and women. *Med Sci Sports Exerc*. 2002;34(1):17–23.
255. Vincent KR, Braith RW, Feldman FA, et al. Resistance exercise and physical performance in adults aged 60 to 83. *J Am Geriatr Soc*. 2002;50(6):1100–7.
256. Wallace RB. Bone health in nursing home residents. *JAMA*. 2000;284(8):1018–9.
257. Wang BW, Ramey DR, Schettler JD, Hubert HB, Fries JF. Postponed development of disability in elderly runners: a 13-year longitudinal study. *Arch Intern Med*. 2002;162:2285–94.
258. Weinert BT, Timiras PS. Invited review: theories of aging. *J Appl Physiol*. 2003;95:1706–16.
259. Welle S, Bhatt K, Shah B, Thornton C. Insulin-like growth factor-1 and myostatin mRNA expression in muscle: comparison between 62–77 and 21–31 yr old men. *Exp Gerontol*. 2002;37(6):833–9.
260. West S, King V, Carey TS, et al. Systems to rate the strength of scientific evidence. *Evid Rep Technol Assess (Summ)*. 2002;(47):1–11.
261. Westerterp K. Daily physical activity and ageing. *Curr Opin Clin Nutr Metab Care*. 2000;3:485–8.
262. Whitehurst MA, Johnson BL, Parker CM, Brown LE, Ford AM. The benefits of a functional exercise circuit for older adults. *J Strength Cond Res*. 2005;19:647–51.
263. Whitmer RA, Gunderson EP, Quesenberry CP Jr, Zhou J, Yaffe K. Body mass index in midlife and risk of Alzheimer disease and vascular dementia. *Curr Alzheimer Res*. 2007;4(2):103–9.
264. Williams P. Coronary heart disease risk factors of vigorously active sexagenarians and septuagenarians. *J Am Geriatr Soc*. 1998;46:134–42.
265. Wolf SL, Sattin RW, Kutner M, O'Grady M, Greenspan AI, Gregor RJ. Intense tai chi exercise training and fall occurrences in older, transitionally frail adults: a randomized, controlled trial. *J Am Geriatr Soc*. 2003;51(12):1693–701.
266. Wolff I, van Croonenborg JJ, Kemper HC, Kostense PJ, Twisk JW. The effect of exercise training programs on bone mass: a meta-analysis of published controlled trials in pre- and postmenopausal women. *Osteoporos Int*. 1999;9(1):1–12.
267. Wray DW, Uberoi A, Lawrenson L, Richardson RS. Evidence of preserved endothelial function and vascular plasticity with age. *Am J Physiol Heart Circ Physiol*. 2006;290:H1271–7.
268. Yaffe K, Barnes D, Nevitt M, Lui LY, Covinsky K. A prospective study of physical activity and cognitive decline in elderly women: women who walk. *Arch Intern Med*. 2001;161(14):1703–8.
269. Yaffe K, Haan M, Blackwell T, Cherkasova E, Whitmer RA, West N. Metabolic syndrome and cognitive decline in elderly Latinos: findings from the Sacramento Area Latino Study of Aging study. *J Am Geriatr Soc*. 2007;55(5):758–62.