

APPLIED PHYSIOLOGY OF AGING

Learning Objectives

1. Define key terms associated with aging
2. Recall what studies on Masters athletes have taught us about primary and secondary aging
3. Describe the effects of age on performance in Masters athletes
4. List typical physiological changes that have been attributed to the aging process
5. Specifically describe changes in the neuromuscular, skeletal, cardio metabolic, and cognitive systems with age
6. Identify the general effects of exercise on the aging neuromuscular, skeletal, cardio metabolic, and cognitive systems.

Introduction

Understanding the physiology of aging is an important aspect of being a successful trainer of mature adults. However, how much do you really need to know? This is what we asked ourselves when putting together the information in this module. You don't need to be an expert in physiology, and you don't need to know all the minute details about how aging affects the skin or hair or intestines and so forth. Our goal is to teach you the aspects of aging physiology that are important and useful for practical application. We also want to help build the case for the Functional Aging Training model that you will learn later. You should walk away from this module with a better understanding of important changes that occur with aging AND with recognition that many of these changes can be minimized through regular exercise.

and inevitable part of the life cycle. All living beings experience a period of growth and maturation followed by a period of decline, which is often accompanied by disease. All living beings experience a period of growth and maturation followed by a period of decline, which is often accompanied by disease, and eventually death. Although the aging process is hard-wired into our systems and cannot be stopped, this doesn't mean that we are completely at its mercy. On the contrary, individuals are able to significantly, and sometimes dramatically, influence how quickly or how well they age. The foods they eat, activities in which they choose to engage, environmental toxins to which they are exposed, and numerous other factors have been shown to either "accelerate" or "slow" the aging process. Yet no one has found a way to stop the aging process altogether.

Organismal senescence (aging) is a natural

Masters athletes are often considered to be

as ideal a model for studying aging, and specifically quantifying **primary aging**, that we have available (see figure below). These athletes have often lived pristine lives – eating well, exercising regularly, avoiding exposure to smoke, and having access to quality medical care. Yet despite doing almost everything right they still age. This is evidenced by the fact that performance records decrease with advancing age in virtually all individual competitive sports – such as track and field, running, bicycling, and swimming (Spirduso et al 2005). The rates of decline are unique to each activity but generally decrease after the age of 40 with an accelerated rate of decline after the age of 70. The question is not IF they will age but HOW they will age. Masters athletes tend to live longer, have fewer diseases, and possess higher levels of function than their less active peer counterparts demonstrating the power of lifestyle to minimize the effects of **secondary aging**.

FIGURE: AGING CONCEPTS

PRIMARY AGING: THE INNATE PROCESS OF MATURATION AND SUBSEQUENT DECLINE WHICH OCCURS IN THE BODY'S CELLS AND PHYSIOLOGICAL SYSTEMS THROUGHOUT THE LIFE SPAN THAT MAKES THE ORGANISM MORE SUSCEPTIBLE TO DISEASE, INJURY AND DEATH. THESE ARE CONSIDERED TO BE "HARD-WIRED" INTO OUR GENETIC CODE AND CANNOT BE ALTERED.

SECONDARY AGING: AGE-RELATED DETERIORATIONS THAT RESULT FROM LIFESTYLE BEHAVIORS (PHYSICAL ACTIVITY, NUTRITION, TOBACCO, ALCOHOL), DISEASE PROCESSES (DIABETES, CANCER, CARDIOVASCULAR DISEASE), ENVIRONMENT (EXPOSURE TO TOXINS, AIR POLLUTION, UV RADIATION), INJURY AND ILLNESS. THESE FACTORS ARE HIGHLY VARIABLE AND CAN BE SIGNIFICANTLY CONTROLLED BY THE INDIVIDUAL TO DELAY SOME AGE-RELATED PROCESSES.

CHRONOLOGICAL AGING: THE NUMBER OF YEARS A PERSON HAS BEEN ALIVE, THEIR CHRONOLOGICAL AGE, HAS LONG BEEN USED AS A WAY TO CATEGORIZE, AND SOMETIMES DISCRIMINATE AGAINST, AN INDIVIDUAL. CHRONOLOGICAL AGE, HOWEVER, IS A VERY CRUDE AND OFTEN INACCURATE MEANS OF DETERMINING HOW "OLD" AN INDIVIDUAL IS FROM THE BIOLOGICAL OR PHYSIOLOGICAL PERSPECTIVE. THE MATURE ADULT POPULATION IS VERY DIVERSE AND THEREFORE AN INDIVIDUAL WHO IS OLDER CHRONOLOGICALLY MAY BE HEALTHIER, FITTER AND MORE FUNCTIONAL THAN THEIR YOUNGER COUNTERPARTS.

USUAL AGING: DESCRIBES HOW THE MAJORITY OF INDIVIDUALS IN TODAY'S SOCIETY "USUALLY" OR "TYPICALLY" AGE. THE TYPICAL OLDER ADULT IS ABLE TO FUNCTION INDEPENDENTLY BUT HAS AN INCREASED RISK OF DISEASE OR DISABILITY. THE DISABILITY RISK IS DUE, IN LARGE PART, TO THE REDUCED FUNCTIONAL RESERVE CAPACITY OF THE INDIVIDUAL AND THEIR DOWNWARD AGING TRAJECTORY. THAT IS, THEY HAVE A REDUCED CAPACITY FOR PERFORMING MORE INTENSE ACTIVITIES

SUCCESSFUL AGING: BASED ON THE RESEARCH BY ROWE AND KAHN [2] THIS IS DEFINED BY THE ABILITY TO MAINTAIN A LOW RISK OF DISEASE AND DISEASE-RELATED DISABILITY; HIGH MENTAL AND PHYSICAL FUNCTION; AND ACTIVE ENGAGEMENT WITH LIFE.

ACTIVE AGING: A CONCEPT ADVANCED BY THE INTERNATIONAL COUNCIL ON ACTIVE AGING AND ADOPTED BY THE WORLD HEALTH ORGANIZATION THAT ENCOURAGES INDIVIDUALS TO BE "ENGAGED IN LIFE" AS FULLY AS POSSIBLE DESPITE HEALTH STATUS, DISEASE CONDITIONS OR SOCIOECONOMIC STATUS. IT RECOGNIZES THE IMPORTANCE OF EACH OF THE SEVEN DIMENSIONS OF WELLNESS – PHYSICAL, INTELLECTUAL, EMOTIONAL, SPIRITUAL, ENVIRONMENTAL, VOCATIONAL, SOCIAL – TO THE OVERALL WELL-BEING OF AN AGING INDIVIDUAL.

Lessons from Masters Athletes

Participation in competition by Masters athletes has risen steadily over the past few decades. In 1987 only 500 participants competed in the annual Huntsman World Senior Games which offers a variety of sports competitions such as basketball, biking, swimming, volleyball and tennis and is open to all athletes age 50 and older. By contrast 9,000 Masters athletes competed in the 2007 competition. In 2005, 9,000 competitors participated in events held across the U.S. as part of the National Senior Olympic Games competition hosted by the National Senior Games Association (NSGA). In 2007 the NSGA reached a milestone by hosting over 12,000 competitors and creating a new age division of 80+ for basketball. The NSGA anticipates participation swelling to 15,000 for the 2011 competition (www.nsga.com).

These athletes represent a growing hodgepodge of individuals with varying abilities, interests, and sporting experience that are part of the global aging boom. The Administration on Aging estimates that in the U.S. alone almost 8,000 adults will turn 60 every day (www.aoa.gov) and many other countries are experiencing similar senior explosions. Some of these Masters are ex-competitive athletes still eager to stay at the top of their game but a growing number were never competitive in their younger years and have just “aged into it.” A growing number of others have picked up their sport late in life. Athletes such as Helen Beauchamp who earned five

gold medals and set one national record at the 2007 National Senior Games although she didn’t enter her first track and field event until the spry age of 64. Although different sports have their specific definitions of what constitutes a Masters athlete, I will be using it to mean athletes over the age of 50.

The growing interest by the Baby Boomers, who began turning 60 in 2006, in health, wellness and anti-aging along with a high amount of discretionary income certainly helps create an environment conducive producing large numbers of Masters athletes. The Senior Olympians are perhaps the models of successful aging as they exhibit high levels of functional capabilities, less chronic disease conditions, a high quality of life, and report higher levels of physical and mental health on subjective surveys (Wright and Perricelli 2008). The most commonly reported conditions are low back pain (25.3%), hypertension (22.9%) and knee osteoarthritis (15.3%), all at lower prevalence rates than their peers in the general population (Wright and Perricelli 2008). This is consistent with a large volume of data showing that physically active adults at all ages are at lower risk of and have lower prevalence rates of many chronic diseases, such as cardiovascular disease, diabetes, and some cancers (Tanaka and Seals 1985; Tanaka and Seals 2008). As the Boomers continue to age and as numerous organizations continue to extol the benefits of regular exercise it is likely that the number of Masters athletes will increase exponentially over the next two decades representing

an unprecedented opportunity for fitness facilities and personal trainers.

Lessons on Health and Function from Masters Athletes

Because of their exemplary physical and mental condition Masters athletes represent a great model for the study of successful or optimal aging. The changes observed with advancing age in this group are considered to be the results of primary (physiological) aging rather than the effects of secondary (lifestyle) aging (Tanaka and Seals 1985). It has been well-established that negative lifestyle behaviors such as smoking, poor diet, weight gain, and sedentary living contribute significantly to a loss of physical function by the age of 60-70. Because of their avoidance of these negative behaviors along with the adoption of many positive behaviors physical performance capability is well maintained to the 7th decade of life suggesting that most adults should also be able to sustain their physiological reserves until then (Tanaka and Seals 2008).

The Effects of Aging on Sports Performance

In the most recent review of the literature regarding age-associated changes in endurance exercise performance Tanaka and Seals (2008) state that “Older athletes strive to maintain or even improve upon the performance they achieved at younger ages, but declines in athletic performance are

inevitable with ageing.” Both running and swimming performance appear to decline in a curvilinear fashion with advancing age although the patterns are not identical and gender is an important factor. In general swimming performance declines to a lesser degree and drops off later than running.

Specifically, running performance is well maintained until around the age of 35 with modest declines in performance until the age of 50-60 with a progressively steeper increase in running times thereafter (Tanaka and Seals 1985). The rate of decline in endurance performance is faster in women especially after the age of 60 and has been shown to be up to threefold greater. Swimming performance, by contrast, does not appear to reach an exponential rate of decline until around the age of 70, a full 10 years later than running performance. In addition, the magnitude of decline is as much as 30% smaller in swimming compared to running. The increased magnitude of decline in running performance with age has been at least partially attributed to an increased incidence of orthopedic injuries compared to swimming which inhibits adequate training volume. Distant-dependent sex differences are observed in swimming with shorter events showing the greatest disparity. The differences declined with increasing distance and disappear altogether in the longest distance events (Tanaka and Seals 2003).

Strength and power performance are similarly affected. The typical aging adult will

lose around 30% of their muscle mass and maximal strength from the time they peak in their 30's to the age of 70 where the decline appears to increase in an accelerated fashion (Spirduo et al 2005). Strength training athletes appear to exhibit similar rates of decline although they remain much stronger than their more sedentary peers because their baseline started out much higher. Even in Olympic weightlifters maximal performance levels decline rather linearly until around the age of 70 where the rates of decline accelerate significantly (Tanaka and Seals 2003). However, even nonagenarians retain the capacity for increasing muscular size, strength and power with adequate resistance training. Therefore, athletes that have not participated in a regular program of weight lifting should be highly encouraged to do so.

Physiological Mechanisms Explaining the Declines in Performance

There are three primary determinants of maximal aerobic capacity that have been identified as contributing to the age-related reductions in endurance performance: VO₂max, lactate threshold, and exercise economy. It has been well-established that VO₂max is the primary determinant of endurance exercise performance in adults. An inverse relationship has been observed between VO₂max and age in trained distance runners. Lactate threshold, defined as “the exercise intensity at which blood lactate levels increase significantly above baseline” (Tanaka and Seals 2003), also contributes to the age-

related declines in endurance performance. However the reduction in lactate threshold impacts endurance performance more in young adulthood to early middle-age while reductions in VO₂max affects performance more beyond middle-age. Although exercise economy, which is the oxygen cost to exercise at a given velocity, is an important determinant of endurance performance it does not appear to be altered with advancing age and thus contributes little to age-associated declines.

There are numerous physiological factors that contribute to the decline in VO₂max with advancing age. Oxygen consumption is determined by central and peripheral factors. The Fick equation states that $VO_{2max} = \text{maximal cardiac output (CO)} \times \text{maximal arterio-venous O}_2 \text{ difference (a-v O}_2\text{)}$. Maximal cardiac output is determined by multiplying maximal heart rate (HR_{max}) by maximal stroke volume (SV_{max}). HR_{max} declines about 0.7 beats per year, SV_{max} declines by 10-20% and peripheral oxygen extraction declines by 5-10% thus reducing VO₂max in older masters athletes compared to younger athletes.

However, another important consideration is training stimulus. While athletes may have great intentions of continuing their training routine, it has been established that neither exercise training intensity nor volume can be maintained for long periods at older ages (Tanaka and Seals 2008). According to Tanaka and Seals (2008), numerous factors may be responsible. First, an increase in family or job

responsibilities may reduce both the time and energy available for intense training. Second, there is an increased incidence of orthopedic injuries among Masters athletes. Third, bio behavioral changes may be at work. The motivation to train may be reduced as the athlete ages as well as the goals underlying the motivation may shift away from being focused on individual performance to health benefits. Lastly, the ‘intrinsic drive’ to exercise may decline with aging as demonstrated in animal studies. Regardless of the reasons or combination of factors an inability to maintain the training stimulus contributes to the rate of decline in VO₂max and endurance exercise performance.

Why Do We Age?

Many theories have been proposed to explain why or how we age from either a biological, physiological, or sociological perspective. Some have focused on primary aging which represents changes that occur with advancing age that are independent of environmental influences or disease processes (Busse 1969). Others attempt to explain factors associated with secondary aging which is the interaction of primary aging processes with disease and environmental influences (Busse 1969). Life Course Theory is one of the prevailing perspectives of aging that recognizes the influence of past events on an older individual’s current state of health and function. There is now a recognition that many factors that are out of the individuals’ control can have an impact on their health,

quality of life, and longevity in later life, such as being born with a low birth weight; the birth mother smoking during pregnancy; being breast or bottle fed; not having access to quality health care services; poor nutrition; and injuries during childhood (Elder et al 2003; Bengtson et al 2009). More recently the concept of active aging has been proposed as a way to promote the benefits of an active lifestyle for increasing longevity and quality of life. Active aging recognizes the importance of active engagement in life in multiple dimensions of wellness such as physical, emotional, social, spiritual, and mental. It is important for fitness professionals that work with older adults to integrate these multiple dimensions of wellness into their programs.

Physiology of Aging

The typical physiological declines associated with aging have been well documented and yet difficulty separating primary and secondary aging processes remains. While literature often reports average declines in physiological systems, there is a high degree of interindividual variability reported in the same literature. This means that while studies may report that a particular component declines on average 30% between the ages of 50 and 80 the actual range of decline among individuals may be as large as 10-60%. Practically speaking, a 10% reduction in that particular component may have no significant effect on the individual while a 60% reduction may cause significant problems and even lead to an active pathology. When considering

these physiological declines, it is important to recognize and appreciate the variability that exists among individuals. Assuming that mature adults of similar age are also similar in regards to health status, disease processes, or functional abilities fails to appreciate the diversity that exists within this population (Table 2).

Table 2: Summary of typical changes in physiological function and body composition with advancing age in healthy humans. Adapted from ACSM Position Stand on Exercise and Physical Activity for Older Adults (2009)

Table 2: Typical Changes in Physiological Function and Body Composition with Advancing Age in Healthy Humans. Adapted from ACSM Position Stand on Exercise and Physical Activity for Older Adults (2009)	
Muscle Strength and Power	Isometric, concentric and eccentric strength decline after age 40 and accelerates after age 65-70. Lower body strength declines faster than upper body strength. Power declines faster than strength.
Muscle Endurance and Fatigability	Endurance declines. The effects of age on mechanisms of fatigue are unclear and task-dependent.
Motor Performance and Control	Reaction time increases (it takes longer to react). Speed of simple and repetitive movements slows. Complex tasks are affected more than simple tasks.
Flexibility and Joint ROM	Significant decreases in hip, spine and ankle flexion by age 70. Muscle and tendon elasticity decreases.
Cardiac Function	Maximal heart rate, stroke volume and cardiac output decline.
Vascular Function	Aorta and its major branches stiffen.
Blood Pressure	BP at rest increases. BP during submaximal and maximal exercise is higher in old vs young, especially in older women.
Ventilation	Chest wall stiffens. Expiratory muscle strength decreases. Work of breathing increases.
Gas Exchange	Reduced surface area for gas exchange in the lungs due to loss of alveoli.
Maximal O Uptake	Declines about 9% per decade in healthy sedentary adults. Rate of decline accelerates with advancing age.
Ventilatory Threshold	Increases with age as a percentage of VO ₂ max.
Walking Kinematics	Preferred and maximal walking speeds are slower. Stride length is shorter; double-limb support duration is longer.
Stair Climbing Ability	Maximal step height is reduced.
Height	Declines approximately 1cm per decade during the 40s and 50s, accelerates after age 60.
Weight	Steadily increases during from 30-70 and then declines after.
FFM	Declines 2-3% per decade from 30 to 70 years of age.
Regional adiposity	Body fat increases during 30s, 40s and 50s with significant accumulation in the visceral region, especially in men.
Bone Density	BMD declines 0.5% per year after age 40. Women lose 2-3% per year after menopause.
Metabolism	Resting Metabolic Rate, muscle protein synthesis rates and fat oxidation all decline with advancing age.

Musculoskeletal and Neuromuscular

Muscular performance declines with advancing age in late life (Spirduso et al 2005). It is commonly reported that strength declines in sedentary older adults at a rate of about 1% per year beginning in their 50's which accelerates to approximately 3% per year once they reach their 70's (Spirduso et al 2005; Chodzko-Zajko et al 2009). However there is a significant degree of variability that exists within the literature that is dependent on type of contraction employed, muscle groups tested, gender, disease processes and physical activity status, to name a few. The declines in muscular performance have been primarily attributed to the loss of muscle mass that is attributed to the aging process (called sarcopenia) since strength is highly correlated to muscle cross-sectional area (Vandervoot 2001). The average individual will lose approximately 40% of their muscle mass between the ages of 20 and 70 (Nair 2005) with a slightly greater loss in the lower extremities compared to the upper extremities (Chodzko-Zajko 2009). It is estimated that anywhere from 22-53% of the older adult population will develop sarcopenia (Iannuzzi-Sucich et al 2002). While the loss of muscle mass is an independent risk factor for the development of disability, it alone does not fully explain the decline in strength associated with aging (Spirduso et al 2005; Rice 2000).

Aging is associated with a preferential decrease in the size of type II (fast-twitch) muscle fibers compared to type I (slow-twitch) fibers; an increase in connective

tissue, altered muscle metabolism; and motor unit remodeling (approximate 1% decrease in number of motor units each year) (Spirduso et al 2005; Rice 2000). The loss of fast-twitch fibers has a major impact on the muscle's ability to generate the necessary force required of specific tasks. These changes can have negative implications for the individual's health and physical functioning which can be at least partially reversed by exercise training. Resistance exercise can increase muscle mass, strength, power, quality (muscular performance per unit muscle volume or mass) and improve muscle metabolism (e.g. glycemic control) even in the oldest-old (Chodzko-Zajko 2009). Aerobic exercise training can improve muscle metabolism but has no effect on muscle mass, strength, power or quality (Chodzko-Zajko 2009).

The ability to coordinate muscular activity into functional movements also declines in old age. Significant declines in functional tasks such as putting on a shirt, managing large and small buttons, zipping a garment, or cutting with a knife decline as does performance on tests of coordination such as finger grasping or interfinger manipulation (Spirduso et al 2005).

Multisensory

Sensorimotor information (collected from the visual and somatosensory systems) is critical to performing both simple and complex movements such as putting on a pair of glasses, dialing a phone, slicing food or buttoning buttons. The visual system

contributes spatial information from the environment such as location, direction and speed of the individual (Spirduso et al 2005). Visual declines are common with aging and often include a reduced ability to detect contrasts, loss of depth perception, decreased illumination within the eye, increased sensitivity to glare (due to scattering of light within the eye), presbyopia (nearsightedness), and loss of peripheral vision. It is common for individuals to become visually-dependent as they get older especially for balance. This means that they become over-reliant on vision to maintain their postural control and upright balance. You may have noticed that older individuals with poor balance have a tendency to look down at the ground and their feet as they walk or they constantly glance down during gait. Visual dependency can be broken and individuals can learn how to use their vision better in order to maintain upright balance during static and dynamic activities. Exercises such as tracking objects with their eyes, focusing on a visual target straight ahead (and therefore not looking at the floor) during gait activities, reducing visual input using sunglasses, and putting a “busy” pattern (such as a checkerboard) in their visual field are all effective ways at training vision.

The vestibular system, located within the inner ear, plays an integral role in balance function. It detects movements of the head and the head’s orientation to gravity (Agrawal et al, 2009). It works in conjunction with the somatosensory/proprioceptive and visual systems especially when these systems do not

have adequate input. The vestibular system is negatively affected by the aging process in many people. There is a decrease in the number of hair cells and vestibular neurons; a decrease in the vestibular-ocular reflex which leads to poorer visual acuity during head movement; and an increased degeneration of otoconia (Whitney and Marchetti, 2007). Otoconia are calcium carbonate crystals in the inner ear which are sensitive to gravity and linear acceleration.

Vestibular dysfunction is typically characterized by vertigo (i.e. dizziness) and imbalance which can lead to the need for medical evaluation and treatment. However, about 32% of older adults have vestibular dysfunction without dizziness. It is estimated that approximately 1/3 of all adults age 50-59 have vestibular dysfunction. The increases to 50% for 60-69 year olds and 70% for 70-79 year olds (Agrawal et al, 2009). The presence of vestibular dysfunction in the general population is especially concerning because it increases fall risk by about 260%. Diabetes also increases risk of vestibular dysfunction by 70%.

Proprioception refers to the sense of knowing where one’s body is in space and is classically comprised of both static (i.e. joint position sense) and dynamic (i.e. kinesthetic movement sense) components. The importance of proprioceptive feedback for the control of voluntary movements is well documented in the literature (Goble et al, 2009). It is clear that proprioceptive deficits in joint position

sense and joint motion sense exist in the elderly and that these declines impact critical sensorimotor tasks such as balance (Goble et al, 2009). The ability to perceive motion of the joints appears to be impaired when movements are performed at slow speeds but may not be impaired when faster speeds are used (Spirduso et al 2005). The proprioceptive system has been shown to be responsive to exercise training. However, it appears that the type of training is critical to inducing improvements. Tai Chi, for example, has a strong relationship to proprioceptive ability and an ability to increase joint position sense.

The somatosensory system integrates with the proprioceptive system by using information about body contact (touch, vibration) to help guide movements. The bottom of the foot is an especially important area for somatosensory input during movement. The sole of the foot has a dense network of plantar receptors such as Ruffini's Corpuscles (skin stretch), Merkel's Disks (texture), Pacinian Corpuscles (deep pressure/vibration) and Meissner's Corpuscles (light touch). These receptors provide critical information to the neuromuscular system. About 80% of all plantar receptors are sensitive to vibration which is appropriate since vibration is how a person detects surface compliancy for stability and locomotion. Plantar receptor density and sensitivity peak around the age of 40. Afterwards, plantar receptor density decreases and sensitivity threshold increases so that by the age of 70 the foot needs twice the stimulus to get the same response. Older

individuals, therefore, tend to have impaired distal lower-extremity proprioception, vibration and discriminative touch which may very likely contribute to poor balance and increased risk of falling. Focused barefoot activities, such as use of the "short foot" exercise, has been shown to improve sensorimotor performance in older adults.

It is said that "you can't teach an old dog new tricks" but research regarding motor learning with older adults shows that this is not true. Older adults are able to improve existing skill performance and learn new skills although they may learn them at a slower rate than younger adults and the manner in which they learn a new skill may be different. In general, they tend to adopt different muscle activation patterns and movement strategies in order to accomplish the new task as a way to compensate for physical losses (Spirduso et al 2005).

The loss of skeletal muscle is accompanied by an increase in fat mass. The data is not clear on how much fat is typically gained throughout middle adulthood but fat mass appears to stabilize in the 6th decade (Spirduso et al 2005). Changes in body fat distribution have been more clearly documented with older adults experiencing an increase in intra-abdominal fat accompanied by a decrease in subcutaneous fat on the limbs (Spirduso et al 2005). Abdominal obesity increases risk for cardiovascular disease and diabetes. These changes are due to a combination of factors including genetics, physical activity levels,

dietary habits, and hormonal changes. Both aerobic and resistance exercise training have been shown effective in reducing fat mass in older adults although more information is needed to determine an optimal exercise prescription (Spirduso et al 2005; Elder et al 2003). Conversely, weight loss in older adults is more closely related to negative consequences for health and physical function and should therefore be monitored with these clients.

Skeletal System

Bone density declines at a rate of approximately 1% per year from age 40-50 for both men and women. In women, bone loss increases to 2-3% per year during and 5-10 years following menopause. Women often lose up to 1/3 of their bone mineral density (BMD) during this time. The rate of bone loss increases for both men and women in the 8th and 9th decades (Spirduso et al 2005). The result is a weaker bone structure that is more susceptible to fracture. Physical activity levels are one of many factors that influence peak bone development and the age-related loss of bone mass. Muscle strength is closely correlated with bone mass indicating that the mechanical stimulus of movement is important in the development and maintenance of BMD.

Osteoporosis is a disease often associated with aging that is characterized by low bone mass and quality which increases bone fragility and the risk of fractures. It is diagnosed through bone mineral density testing. A BMD of 2.5 standard deviations below the mean for young

women defines osteoporosis whereas a BMD of 1.0 to <2.5 standard deviations below the mean for young women defines osteopenia (Spirduso et al 2005). Approximately half of all women and 12% of all men over the age of 50 will have an osteoporosis-related fracture (Rose 2010). The most common fracture sites are the spine, hips, and wrists. Weight-bearing cardiovascular exercise, such as jogging or jumping rope, and high-intensity resistance exercise have been shown to either halt the loss of or slightly improve BMD in older adults. Individuals with osteoporosis should avoid excessive spinal flexion (especially when accompanied with rotation) and activities with a high risk of falling.

Degenerative changes also occur in the joints with advancing age including loss of lubrication and articular cartilage damage. Osteoarthritis (OA), or degenerative joint disease, is characterized by pain and stiffness in the joints and is the most common form of arthritis (Rose 2010). Approximately 50% of adults over the age of 65 and 85% of adults over the age of 75 have OA (Spirduso et al 2005). It most often develops in the hips, knees and back and is the leading cause of disability in the United States.

The evidence shows that exercise training does not exacerbate pain or disease progression as once thought. Rather, aerobic and resistance exercise training are effective at decreasing pain and improving function in individuals with OA (Rose 2010) and should be included as essential components of a treatment plan for

OA. Recommendations for individuals with OA include avoiding high-impact activities that may irritate or further damage joints, muscle strengthening using lower resistance levels and higher repetitions around the affected joints, low-impact aerobic exercise (land-based or aquatic), avoiding activities on days when the joint is inflamed (red, swollen, painful), and stretching to improve pain-free joint range of motion.

If the condition progresses then a joint replacement may be warranted. OA is the most common reason for joint replacement surgery among older adults. Total knee and total hip replacement surgeries have a very high success rate for significantly reducing pain and increasing function. Advances in technology and surgical techniques are further increasing success rates and reducing recovery times. Depending on the location and type of surgery individuals may have limitations in specific movements they are able to perform.

Cardio Metabolic

Maximal aerobic capacity, as measured by maximum oxygen consumption (VO_2max), decreases with advancing age at a rate of about 30-40% per decade (Karavidas et al 2010). This decrease is due to several factors including reductions in cardiac output and arteriovenous oxygen difference. The reduction in maximum cardiac output is due primarily to the reduction in maximum heart rate which decreases by about 1 pulse/min/year. The ejection fraction of the left ventricle

during exercise also decreases from 85% for someone in their thirties to about 70% for someone in their nineties (Karavidas et al 2010). Blood vessels tend to become thicker and stiffer (known as arteriosclerosis) which makes them less compliant to accepting blood. Compliance of the common carotid artery decreases by as much as 50% from the age of 25 to the age of 75 (Karavidas et al 2010). The stiffness of these arteries increases risk of hypertension.

Aerobic exercise training of sufficient intensity ($>60\% \text{VO}_2\text{max}$), frequency and length (> 3 days per week for > 16 weeks) is able to significantly improve VO_2max in older adults (Chodzko-Zajko et al 2009) by about 16% although the magnitude of improvement is generally less in those over 75 years of age. Interval training programs that utilize alternating periods of higher and lower intensities may improve VO_2max even more. Other cardiovascular adaptations include a lower heart rate at rest and at any submaximal exercise workload; smaller rises in blood pressures during submaximal exercise; increased maximal exercise stroke volume; and reductions in large artery stiffness.

Cardiovascular disease (CVD) is common among older adults with about 84% of deaths related to cardiovascular disease occurring in people 65 years or older. Cardiovascular disease can lead to a myocardial infarction, stroke (or transient ischemic attack or TIA) and death. Age, however, is no longer considered to be an independent risk factor

for CVD. Active individuals of all ages have a lower prevalence of CVD than their inactive counterparts at any age. Physical activity volume (including exercise) is inversely related to death from all causes in a dose-response manner, meaning that the higher the volume of physical activity the lower the risk of dying. Moderate-intensity activities for at least 30 min on most, preferably all, days of the week is sufficient to reduce risk of premature death. This is a goal that is very attainable for many older adults.

Hypertension is a risk factor for CVD and is a prevalent concern in the older population. Exercise training is recommended for the prevention and management of hypertension. Chronic aerobic exercise can decrease both systolic and diastolic pressure by approximately 5-7mm Hg (ACSM 2014). Individuals with controlled hypertension can safely exercise if some basic guidelines are followed. They include:

- Individuals with severe or uncontrolled hypertension should be evaluated by a physician prior to initiating an exercise program
- Exercise should be avoided if resting blood pressure is >200/110
- Perform an extended warm-up and cool-down and monitor for post-exercise hypotension
- Monitor blood pressure during exercise and discontinue if blood pressure exceeds 220/105
- Avoid performing a Valsalva maneuver during resistance training

- Avoid high-intensity resistance exercise with high weights and low repetitions

Common complications and co-morbidities for individuals with CVD include diabetes, obesity, hypertension, dysrhythmias, angina, shortness of breath, reduced exercise capacity, and intermittent claudication (associated with peripheral arterial disease) among others. While it is outside the scope of the fitness professional to prescribe exercise for the management of these conditions it is prudent to be able to identify signs and symptoms associated with them and to be able to act quickly when they occur. In addition, individuals with CVD should obtain appropriate medical clearance before beginning an exercise program.

Type 2, non-insulin-dependent, diabetes mellitus rates has increased considerably in the older adult population over the past decade (Rose 2010). Diabetes is an independent and strong risk factor for developing cardiovascular disease and is the leading cause of adult-onset blindness, non-traumatic lower limb amputations, and renal (kidney) failure. Diabetic older adults should engage in regular exercise and follow a heart-healthy diet in order to lose body fat, improve glycemic control, and reduce their need for medications (Spirduso et al 2005; Rose 2010). Aerobic exercise training is the most effective method for improving insulin sensitivity and glycemic control but resistance exercise training is also beneficial. Diabetic individuals should adhere to the following

guidelines when starting and maintaining an exercise program:

- Monitor blood glucose before, during and after exercise. Exercise should be avoided if pre-exercise blood glucose is less than 100 or greater than 300 mg/dl
- Exercising at the same time of day will allow easier tracking of the exercise effects on blood sugar control
- Keep a quick-acting sugary snack on hand at all times, such as raisins or juice, in case of a hypoglycemic (low blood sugar) episode
- Check feet regularly for cuts and/or ulcers that are not healing properly
- Avoid exercising late at night
- Adopt a low to moderate intensity program and avoid high-intensity exercise if relatively new to exercise

Several age-related changes occur in the respiratory system including changes in the structure of the lungs and airways, changes in lung volumes, impaired efficiency of gas exchange and alterations in the ventilator pump (Spirduso et al 2005). Although total lung capacity remains constant throughout life, residual volume and functional residual capacity increase about 25% while vital capacity decreases by about 25%. Despite these changes it does not appear that the respiratory system limits exercise training.

Cognition and Emotional Well-Being

While it is commonly believed that senility and dementia are normal aspects of aging research indicates that age-related cognitive decline is attributable more to the secondary

effects of lifestyle, specifically health and fitness levels, rather than the primary effects of the aging process (Spirduso et al 2005). There are numerous aspects to cognition such as processing speed, visuospatial processing, controlled processing, and executive control, and each may be more or less affected by the aging process, health status, and physical activity participation. Evidence indicates that diseases such as diabetes, cardiovascular disease, and cerebrovascular disease impair neuropsychological function. Hypertension has been linked very strongly to cognition with evidence that it can slow sensory-motor speed and perceptual processing speed (Spirduso et al 2005).

Habitual physical activity is associated with a reduced risk of dementia and cognitive decline in older adults (Chodzko-Zajko et al 2009) and conversely decreases in physical mobility are linked to cognitive decline. Even a single bout of aerobic exercise can improve memory, attention, and reaction time for a short period of time. Long-term participation in both aerobic and resistance training programs lead to improvements in cognitive function especially when combined. Programs that utilize cognitive challenges in combination with aerobic exercise typically lead to larger improvements (Chodzko-Zajko et al 2009). The positive effects of regular exercise appear to be largest for tasks that are more complex and which require executive control. Exercise of low to moderate intensity conducted over a longer period of time appears to be more effective than short-term higher intensity programs.