

MODULE 2

APPLIED PHYSIOLOGY OF AGING

Learning Objectives

1. Define key terms associated with aging
2. Define the contributions of genetics, primary aging and secondary aging to the health and longevity of older individuals
3. Describe the effects of age on performance in Masters' athletes
4. Specifically describe changes in the neuromuscular, skeletal, cardiovascular, sensory, balance, mobility and cognitive systems with age
5. Identify key lifestyle factors that affect how well and how long a person lives

Introduction

Understanding the physiology of aging is an important aspect of being a successful trainer of mature adults. However, you don't need to be an expert in physiology and you don't need to know all of the minute details about how aging affects every system in the body (e.g. skin, hair, gut) to be able to work effectively with this population. This module will teach you the aspects of aging physiology that are the most important and useful for fitness professionals and will establish a strong foundation for the Functional Aging Training model that will be explained in detail later. This section will also discuss how many of the negative changes associated with aging are actually due more to poor lifestyle choices and can be minimized, negated or even reversed by a targeted exercise program.

What is Aging?

Organismal senescence (biological aging) is a natural and inevitable part of the life cycle. All living beings experience a period of growth and maturation followed by a period of decline, often accompanied by disease, and which culminates eventually in 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.

Master's 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 tobacco and excessive alcohol use and having access to quality medical care. Yet despite doing almost everything "right" they still age and eventually die. 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 (Spiriduso 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. Master's 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.

Functional Aging: A concept promoted by the Functional Aging Institute that focuses on the ability of an individual to maintain high levels of physical abilities as they get older so that they can continue to do the things they need to do, like to do and dream of doing.

Lessons from Master's Athletes

In the U.S., participation in competition by master's athletes has risen steadily over the past few decades. In 1987, 2,500 athletes competed in the first National Senior Games (also called the Senior Olympics) which offers competition in a variety of individual and team events such as track and field, weight lifting, basketball, biking, swimming, volleyball and tennis and is open to all athletes age 50 and older. In 2007, 20 years after the very first games, that number had exploded to over 12,000 athletes and a new age division of 80+ for basketball was created. In 2019, the games featured 20 different sports and hosted close to 14,000 athletes (www.nsga.com) with some of the most interesting competition occurring in the 90+ and 100+ year old sprint races.

These athletes represent a growing mix of individuals with varying abilities, interests and sporting experience that are part of the global aging boom. Some of these master's athletes are experienced competitive athletes still eager to stay at the top of their game and have just "aged into it". By contrast, however, are a growing number of master's athletes who 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 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 master's athlete we will use it to refer to athletes over the age of 50.

These 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) than their

peers. The most commonly reported conditions among these athletes are low back pain (25.3%), hypertension (22.9%) and knee osteoarthritis (15.3%), but these are all at much 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 population continues to age and as numerous organizations continue to extol the benefits of regular exercise it is likely that the number of master's athletes will increase exponentially over the next two decades representing an unprecedented opportunity for fitness facilities and personal trainers.

Since they are leading such active, healthy lifestyles the changes observed with advancing age in this group are considered to be the results of **primary** (physiological) aging rather than **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).

However, despite living active and often pristine lifestyles, these athletes still experience declines in their physical performance. It is clear that while everyone will endure the negative affects of primary aging it is really the impact of secondary aging that will determine how well and how long we will live. Negative lifestyle choices can accelerate the aging process while positive lifestyle

choices can slow the aging process. More specifics about these physically elite and physically fit older adults will be discussed later in this course.

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.

Life Course Theory recognizes that many factors from early in life and that are often out of the individuals' control can have an impact on their health, quality of life and longevity in later life. Examples include 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).

Genetics also influence health and longevity but its role has been largely over-stated in the general public. Genetics only account for about 20-25% of the variability in health and longevity in humans which means that lifestyle accounts for about 75-80%. To put it another way, lifestyle is 3-4x more important than genetics when considering how healthy and how long a person will live. This is great news because it empowers people to live healthy lifestyles rather than thinking they are trapped by "bad" genes. The field of epigenetics has revealed that lifestyle can influence our

DNA by either turning genes on or off. Consider the following example. A person has a family history of diabetes and cardiovascular disease so they are likely genetically predisposed to developing these two conditions as well. However, having these “bad” genes does not mean that the genes will actually express themselves. If this person eats healthy, exercises regularly, avoids tobacco use and drinks little to no alcohol it is more likely that they will not develop diabetes or cardiovascular disease. Their lifestyle has turned “off” these bad genes. However, if this person were to not live a healthy lifestyle it is MORE likely that they will develop these conditions because she is already predisposed to them. It has been said the “genetics loads the gun but lifestyle pulls the trigger” is mostly true because we could also say that lifestyle can put the safety on.

As we discuss the changes that typically occur with advancing age it is critical to remember that these changes are likely due more to lifestyle (secondary aging) than the aging process itself. The typical older adult is not as active as they should be and, in most cases, have not been as active as they should have been over the course of their entire lives. What is often considered “normal aging” is more likely the effects of deconditioning and may not be “normal” at all.

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 (physiological system) declines on average 30% between the ages of 50 and

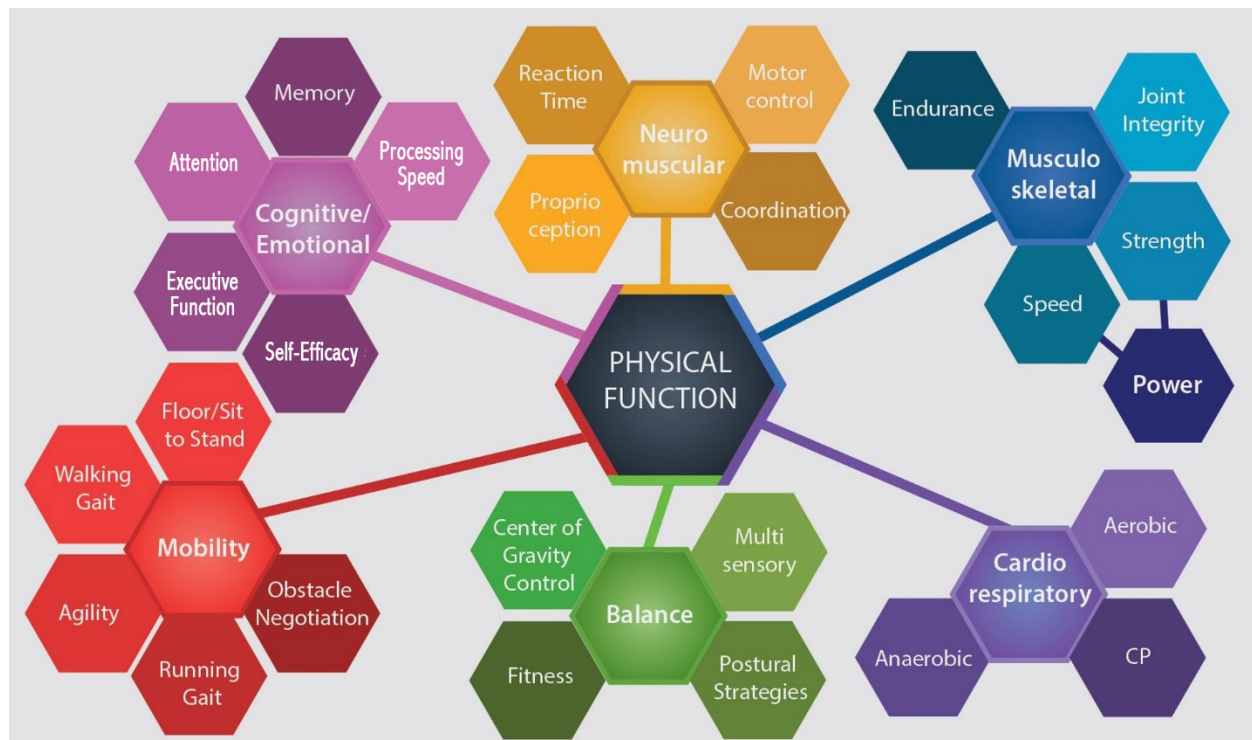
80 the actual range of decline among individuals may be as large as 10-60%. Practically speaking, a 10% reduction in that particular component may have no significant effect on the individual while a 60% reduction may cause significant problems and even lead to an active pathology. When considering these 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.

In order to prepare you for the Functional Aging Training Model there are six primary physiological systems that will be discussed. These are the six functional domains that will serve as a roadmap for proper assessment and programming for your older clients. It is important to understand that while these six systems are listed as separate entities the reality is that all of these systems are interconnected. Each of these systems, their relationship to one another and how they contribute to a person's functional abilities will be discussed in more detail later on.



Skeletal Muscle Changes with Aging

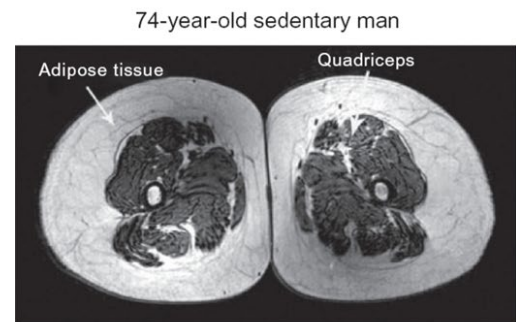
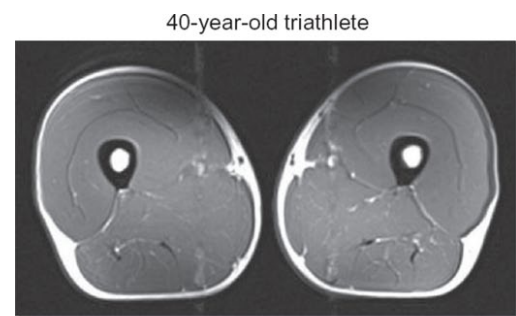
Muscular performance declines with advancing age in late life (Spirduo et al 2005). It is commonly reported that strength declines in sedentary older adults at a rate of about 1% per year beginning in their 50's which accelerates to approximately 3% per year once they reach their 70's (Spirduo et al 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)

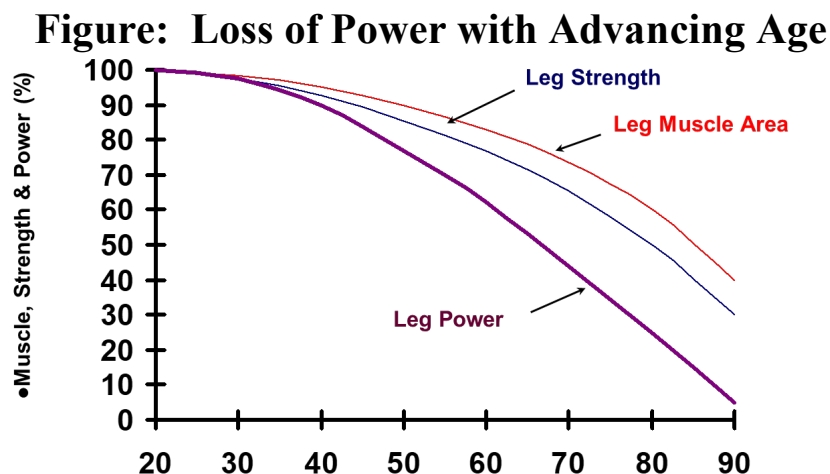
with a slightly greater loss in the lower extremities compared to the upper extremities (Chodzko-Zajko 2009). It is estimated that anywhere from 22-53% of the older adult population will develop sarcopenia

(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 (Spirduo et al 2005; Rice 2000). As seen in the image, it is possible to retain muscle mass into late adulthood through regular vigorous exercise. The 74-year-old triathlete has the same



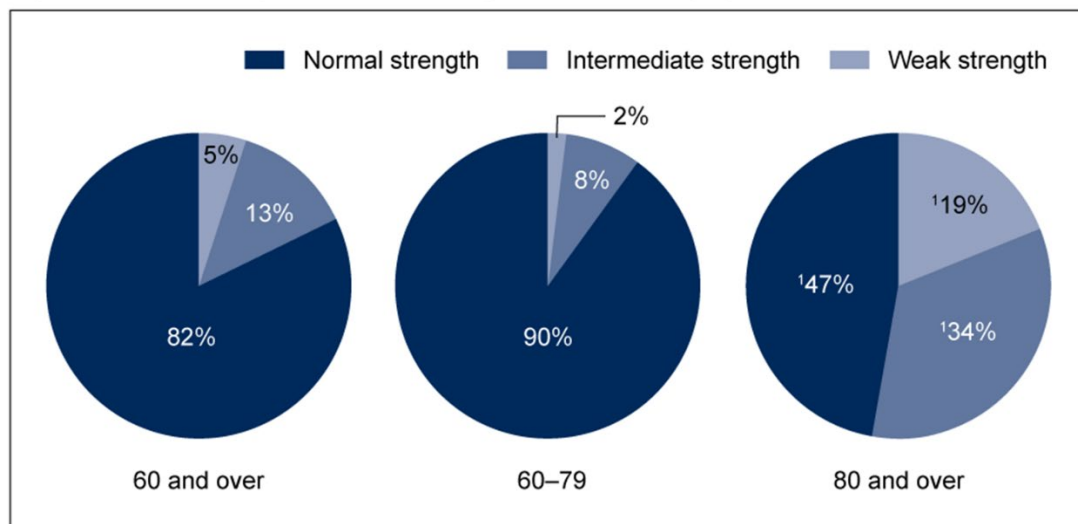
muscle mass and fatness as the 40-year-old triathlete while the 74-year-old sedentary man shows a significant decrease in muscle mass and increase in fat.

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. This loss of muscle power can have negative implications for the individual's health and physical functioning which can be at least partially reversed by exercise training. Muscle power has been shown to decline earlier and more steeply than does muscle strength (see figure). Power is also more closely associated to the successful performance of many functional activities than is muscle strength making it a key factor that needs to be recognized and addressed in exercise programs. Numerous systematic reviews and expert recommendations highlight the importance of using explosive, powerful resistance exercise movements for older adults of all functional ability levels.



Although the loss of muscle mass, strength and power is a hallmark feature of aging it varies widely between individuals and is more prominent in women and some countries. In the U.S. approximately 10% of 60-79-year olds have lower than normal muscle strength, as measured by handgrip strength, but that number jumps to 53% in the 80+ age group (see figure below) according to data from the Centers for Disease Control (<https://www.cdc.gov/nchs/products/databriefs/db179.htm>). Weak strength was defined as <26kg for men and <16kg for women. According to the same data, non-Hispanic Asians have the highest rate of lower than normal strength with Hispanics coming in second.

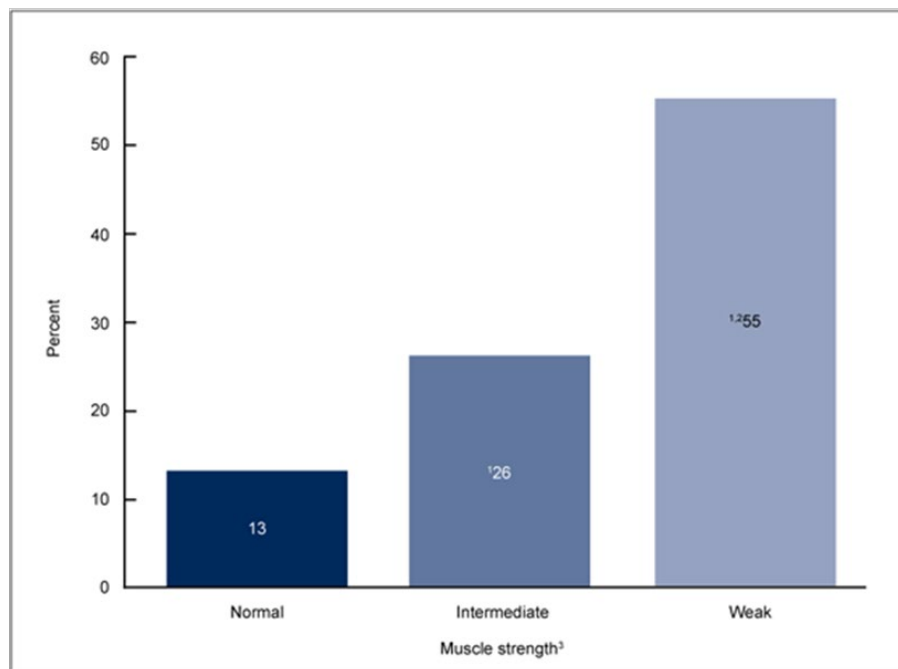
Figure 1. Muscle strength status in adults aged 60 and over, by age: United States, 2011–2012



¹Significantly different from those aged 60-79 in the same muscle strength category, $p < 0.05$.
SOURCE: CDC/NCHS, National Health and Nutrition Examination Survey, 2011–2012.

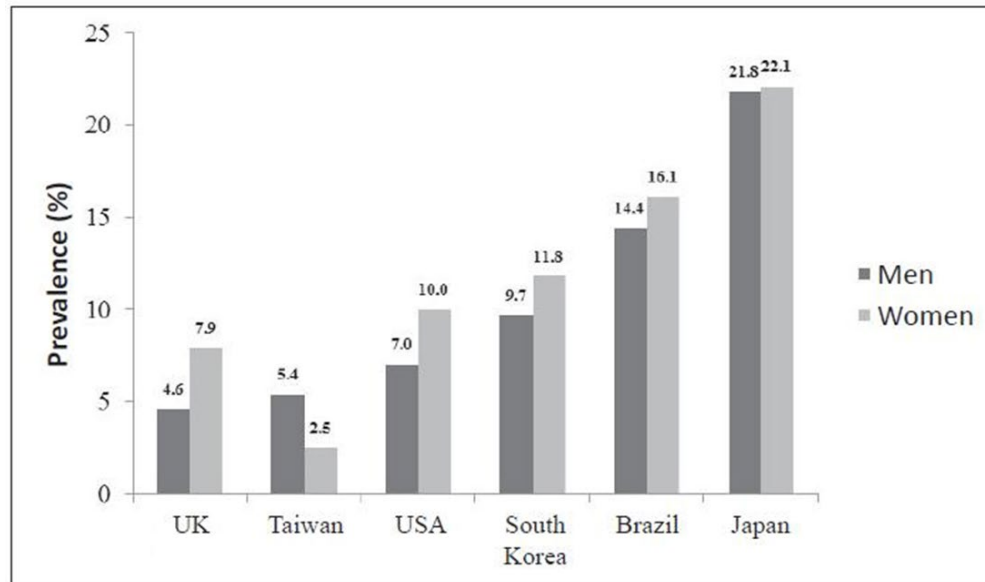
Low levels of muscle strength are associated with increased difficulty with daily tasks such as rising from a chair (see figure below).

Percentage of adults aged 60 and over with difficulty rising from a chair, by muscle strength



The prevalence of sarcopenia (the loss of muscle mass and strength with advancing age) may be higher in some countries compared to others. According to a review of the literature (Says et al 2015) Japan has the highest prevalence of sarcopenia among older adults followed by Brazil, South Korea and the U.S. (see figure below: https://www.scielo.br/scielo.php?pid=S1809-98232015000300665&script=sci_arttext&tlng=en#B08).

Figure: Prevalence of Sarcopenia around the World



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). Resistance exercise strategies, techniques and movements that improve strength and power will be detailed later in the course.

The loss of skeletal muscle mass is accompanied by an increase in both subcutaneous and intramuscular 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 (Spiriduso 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 (Spiriduso 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 (Spiriduso 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.

Another hallmark of the aging process is the loss of collagen throughout the body. This is often noticed in the form of skin wrinkles in older adults. However, the loss of collagen in soft tissues with aging can be more serious leading to an increase in stiffness (loss of elasticity) in muscles, tendons and ligaments which impairs overall flexibility, joint mobility and shock absorption during loading. All of the major joints can be affected but losses in thoracic spine, hip and ankle mobility are common and can have a significant impact on an individual's functional abilities. Proper joint mobility is a necessary pre-requisite for proper movement patterns. When joint mobility is lacking the body finds a way to compensate for this loss which often leads to problems in other areas of the kinetic chain. For example, loss of ankle dorsiflexion causes a backward shift of body weight during a squatting pattern which is often compensated for by excessive forward lean.

Neuromuscular Changes with Aging

The ability to coordinate muscular activity into functional movements (motor performance) 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 can decline significantly as does performance on tests of coordination such as finger grasping or interfinger manipulation (Spiriduso

et al 2005). The variability of motor performance for an individual also increases with age (their ability to perform a task consistently decreases) leading to less predictable and less accurate performance. However, these age-related changes are also highly variable between individuals with some older adults having much greater impairments in motor function compared with others of the same age and sex. The deficits in motor performance are due to a number of related changes to motor units (number, morphology, properties) and altered input from peripheral, spinal and supraspinal centers. Changes in the sensorimotor systems (visual, vestibular, somatosensory) contribute to the declines in motor performance.

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). There is also evidence to indicate that older adults may need a higher volume of practice on a particular motor skill or pattern in order to retain it long term.

Fine motor skills, the ability to make movements using the small muscles in the hands and wrists, often decline in old age which could impact a person’s ability to remain independent and perform activities they like to do. Some strategies to help retain or improve these fine motor skills include: knitting, puzzles, pick up small objects, put pegs in a pegboard, practice buttoning and unbuttoning clothes, play a musical instrument, finger painting, hand exercises, tying a bow or knot, manipulate

tools like scissors, employ hand division (use some fingers at a time and not others), promote bilateral integration (using two hands together) and coordinate hand-eye movement (like catching a ball).

Sensorimotor information 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 losses 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. These losses must be accounted for during exercise sessions by providing well-lit areas; clear contrast in flooring; having them wear their glasses; and avoiding situations in which their visual losses might put them at risk of injury, such as falling.

It is also common for individuals to become visually-dependent as they get older especially for activities that require balance and gait. While all three sensory systems provide valuable input, a person can become over-reliant on vision to maintain their postural control and upright balance. Older individuals with poor balance often tend to look down at the ground or their feet during gait and are more unsteady when they cannot do so such as in low-light environments or when carrying an object that blocks their downward vision. 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.

Skeletal System Changes with Aging

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 accelerate disease progression as was 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.

Cardiovascular Changes with Aging

Maximal aerobic capacity, as measured by maximum oxygen consumption ($\text{VO}_{2\text{max}}$), 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 $\text{VO}_{2\text{max}}$ 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 $\text{VO}_{2\text{max}}$ 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 the leading cause of death globally. It 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.

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.

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.

Balance and Mobility Changes with Aging

Balance and whole body mobility (the ability to move around within your environment including getting up and down from a chair or the floor and having a proper gait pattern) are domains that are typically affected by the aging process and get worse with advancing age. Losses in flexibility, neuromuscular control, movement speed, vision, vestibular function, cognition, posture and more all contribute to the problem of increased fall rates among older adult. Approximately one-third of community-dwelling adults over the age of 65 and 50% of those over 80 fall each year with fall rates increasing for institutional residents. Between 20% and 30% of fallers suffer injuries that reduce their mobility and potentially compromise their independence. Falls are the leading cause of injury deaths for older adults. Approximately 5% of falls result in fractures with hip fractures being the most common (more than 95% of hip fractures are caused by falling). Of those who suffer a hip fracture 50% never regain their ability to walk and 20% die within six months. Falls are also the leading cause of traumatic head injuries in older adults.

According to data from the U.S. Centers for Disease Control, 29 million older adults fell in 2014 (1 in 4 older adults) with 24% of those falls requiring medical treatment or restricted activity for at least a day and 30,000 deaths. Those numbers are expected to skyrocket to 74 million falls with 12 million injuries by the year 2030. The rate of falls is increasing faster than the older adult population is growing. Between 2007 and 2016 fall death rates in the U.S. increased 30%. Some experts have speculated that the rise in death rates is likely due to an increase in the 85+ year old

population which are often frailer and have multiple chronic disease conditions making a fall more likely to result in death. According to the data, women fall more often than men and account for $\frac{3}{4}$ of all hip fractures.

Even non-injurious falls can have serious long-term consequences. When older adults fall (even if they do not get injured) they often experience an increase in their fear of falling again (a major risk factor for falling). Because of this fear they start to limit their daily activities in order to stay “safe”. For example, they may choose to stop doing chores in the yard because of the uneven ground or carrying the laundry down the stairs. This leads to them becoming more physically inactive which accelerates their physiological losses, worsens their balance and increases their fall risk even more. As their physical capabilities worsen they restrict their activities even further which continue to exacerbate their fall risk.

Because of the rise in the prevalence and rate of falls among older adults many governments, like the U.S., are calling for more screening by physicians and other healthcare providers. The U.S. Centers for Disease Control created a program called STEADI which stands for Stopping Elderly Accidents, Deaths and Injuries targeting primary care providers. The program teaches these providers how to screen for falls and balance deficits and then refer patients to appropriate therapists, programs and fitness professionals. Similarly, the ICOPE guidelines from the World Health Organization includes a pathway for screening older patients for a decline in mobility, managing the patient’s conditions that are impacting mobility and referring to appropriate therapists, programs and fitness professionals. It is hopeful that with increased screening more older adults will be able to get the exercise interventions they need to improve their balance before they suffer an injurious or even deadly fall.

Cognitive Changes with Aging

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, memory abilities, attentional processes and executive functioning, and each may be more or less affected by the aging process and lifestyle factors. Evidence indicates that diseases such as diabetes, cardiovascular disease and cerebrovascular disease impair neuropsychological function. The link is so strong that many experts have stated that heart health equals brain health. You're your heart healthy and you will keep your brain healthy. Even hypertension, a risk factor for cardiovascular disease, has been linked very strongly to cognition with evidence that it can slow sensory-motor speed and perceptual processing speed (Spirduso et al 2005). Gait speed, grip strength, dual-task ability, and lower extremity strength have all been correlated to cognitive functioning, and therefore it is important to curate comprehensive exercise programs if cognitive decline is to be optimally slowed.

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 certain types of memory, attention and reaction time for a short period of time, although the research in this area is lacking. Long-term participation in both aerobic and resistance training programs lead to improvements in cognitive function, especially when combined, which is deemed a multi-modal training program. Programs that utilize cognitive challenges in combination with aerobic exercise can lead to even

larger improvements (Chodzko-Zajko et al 2009), ideally in combination with a multi-modal training program.

The positive effects of regular exercise appear to be largest for tasks that are more complex and which require executive control, such as those found in coordination and skill-based exercises. Moderate intensity exercise conducted over a longer period of time appears to be more effective than short-term programs, and both low and high intensity-forms of exercise have been found to have their own unique impacts on cognition. An ideal exercise program likely requires a variety of low, moderate and high intensity modalities, as well as exercise types. Such programs are likely to slow cognitive decline more than a single modality or shorter-term programs, although this programming may be different in populations with cognitive and neurological issues.

Normal aging is not normally well understood by the general public. Just as the body ages, so does the brain. Generally speaking, structural and functional aspects of the brain decline with age, and the inclusion of cognition further highlights this phenomenon. Some aspects of cognition decline normally with age, such as perceptual processing speed and short-term (or working) memory abilities. Depending upon age-related beliefs, certain individuals may believe more accelerated cognitive decline is “normal”, when in actuality it may represent early stages of dementia, such as Alzheimer’s Disease. A study by the Alzheimer’s Association that included 12 countries found that 59% of people worldwide incorrectly believe that Alzheimer’s disease is a typical part of aging and 40% incorrectly believe that it is not fatal (www.alz.org/global/InternationalSurvey.pdf). Their data also showed that Alzheimer’s disease is the second most feared condition.

There are several changes that normally occur to the brain with age:

- The size and function of neurons decline with age.

- Neurons may die off or lose function via a reduction in myelin, the sheath surrounding neurons created by oligodendrocytes that increase signal speed.
- Regions of the brain related to memory, such as the hippocampus, begin to shrink with age, making it harder to form new memories.
- The brain changes in volume and in brain weight. This can be due to neuron numbers, cortical thickness changes, and decreased blood flow.
- By age 80, a healthy brain is 5% lighter than a brain in middle adulthood. The frontal lobes atrophy, leading eventually to decreased executive functioning.
- The brain's ability to change in response to experiences is most available early in life. As age increases the ability for the brain to change in response to experience decreases, and the amount of effort required to make these changes increases with time.

This chart demonstrates some of the mechanisms that occur with normal cognitive aging versus those that occur with Alzheimer's Disease, the most common subtype of dementia. Alzheimer's Disease is not a normal part of aging but is a specific disease process the same as cardiovascular disease or cancer. It is important to distinguish between normal cognitive changes with aging and the onset of dementia.

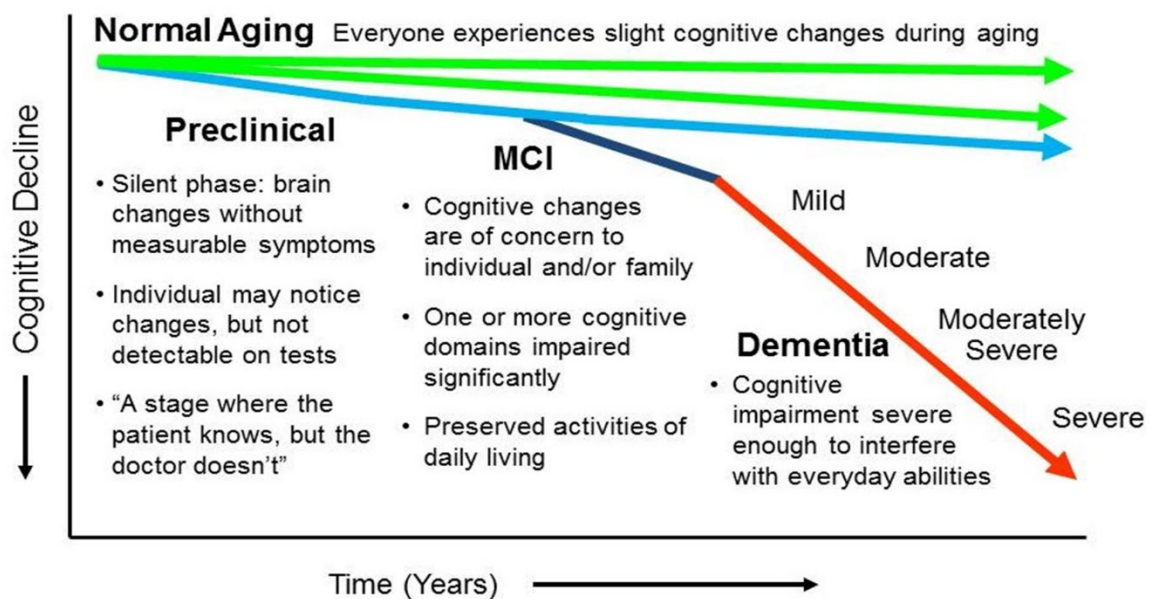
Normal Cognitive Aging	Alzheimer's Disease
Some neuronal decline	Loss of neurons extensive
Some variable changes in cognition	Severe & progressive decline
Some neurodegeneration occurs	Severe & chronic neurodegeneration

General slowing of daily activities	Worsened activities of daily living
Losing things from time to time	Misplacing things with little recall
Occasional word-finding issues	Difficulty holding a conversation
Missing a monthly bill	Inability to manage budget

Due to the global aging phenomenon the rate of dementia is increasing. In the U.S. approximately 18% of older adults have dementia. According to the World Alzheimer's Association there is a new case of dementia somewhere in the world every 4 seconds and the number of people with dementia is expected to increase to 76 million by 2030 and 135 million by 2050 – which is a 300% increase from 2013 (44 million). The following is the list of the 10 countries with the highest death rates from dementia (www.worldatlas.com):

- 1) Finland
- 2) USA
- 3) Canada
- 4) Iceland
- 5) Sweden
- 6) Switzerland
- 7) Norway
- 8) Denmark
- 9) The Netherlands
- 10) Belgium

Even more older adults have Mild Cognitive Impairment (22% of U.S. adults over the age of 70) or have preclinical declines in cognitive function. The graph below shows the continuum of cognition. The green and light blue arrows refer to individuals that are experiencing normal cognitive changes as they get older while the dark blue and red arrows refer to individuals that have more pronounced changes in cognition which indicates a disease process such as dementia.



Conclusions

Aging affects everyone...but not in the same ways or to the same degrees leading to huge variations in the health and physical abilities of older adults – even those that are the same age. This makes chronological age a crude and rather poor indicator of a person's physical abilities. How well or how poorly an individual ages is primarily due to the lifestyle choices they make each and every day. Their lifestyle has more of an impact on their health, longevity and quality of life than genetics or biological aging. How active are they? What do they eat? Do they smoke? Do they drink alcohol and how much? These are all important factors that impact the aging process.

However, there are also other factors that can make a huge difference in how long and how well a person lives. What better way to learn what it takes to live a long, healthy life than by taking lessons from the people that have done it? In the next section we will explore lessons on healthy aging gleaned from research on people living in the Blue Zones.