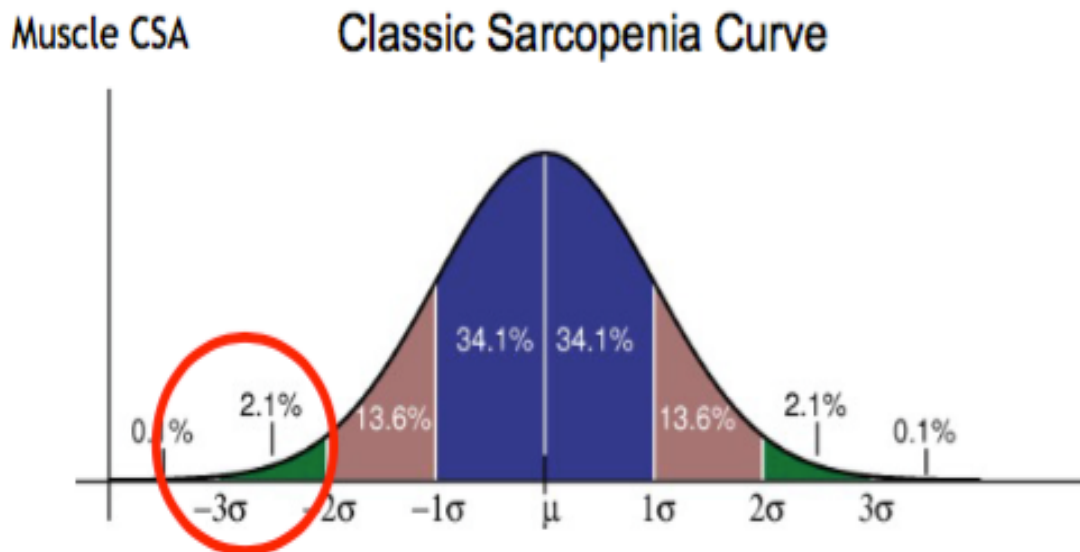


Aging of the Bodily Systems

Age-Related Changes to the Neuromuscular System

A system of major importance to the daily life of an active ager is neuromuscular function. Whether it is doing a DIY home improvement project in the yard or lifting the kayak up and down off of the roof racks of the car, a healthy neuromuscular system is necessary to produce the strength and power necessary to accomplish these tasks. With age, the neuromuscular system undergoes substantial atrophy and reorganization. Due to genetic and lifestyle factors, age results in the loss of contractile proteins within muscle cells. This causes muscle fibers to atrophy. When muscle cross sectional area is less than ~95% of a gender-matched, younger sample, the older adult is said to have SARCOPENIA (9).

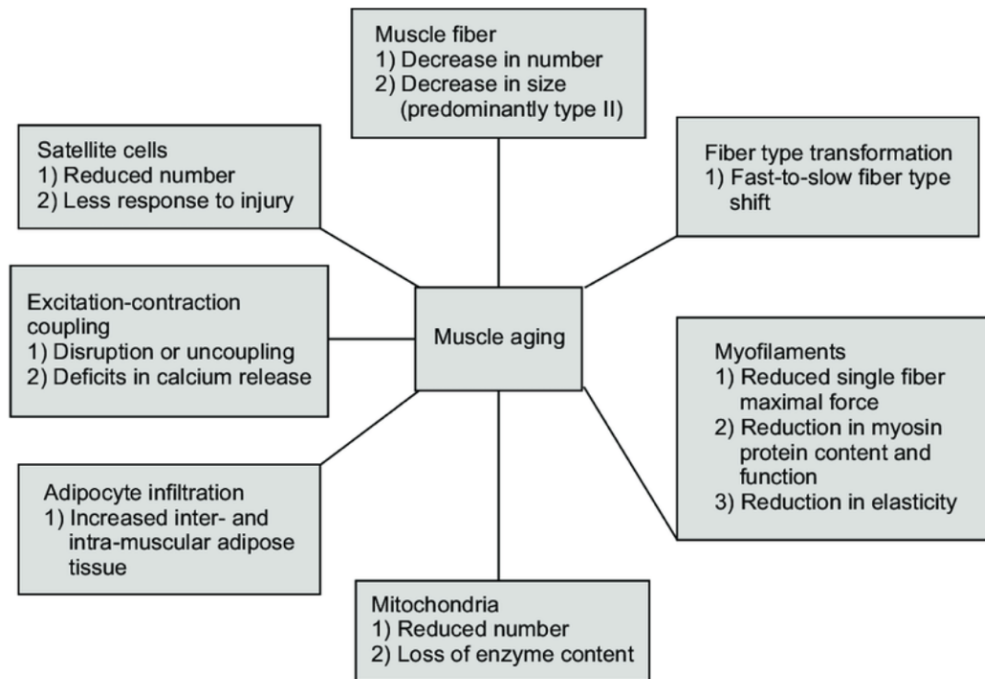


Although and active ager is unlikely to have this condition due to their highly engaged lifestyle, this is still a condition that must be guarded

against because independent living is threatened due to muscle mass reaching this critically low level.

In young and middle age, muscle performance (i.e., muscle strength and muscle power) is strongly correlated with the amount of muscle mass a person has accrued. However, this relationship becomes less correlated with age. Many older adults with adequate muscle mass still will exhibit major losses of muscle strength and muscle power leading to losses in functional activities such as walking speed and lifting capacity. Even though muscle mass atrophy may not reach the level of diagnosed sarcopenia, there is often a loss of muscle quality which reduces function. Both fat and collagen, a rigid connective tissue, increases within the musculoskeletal matrix. These reduce range of motion and replace contractile proteins which then reduce force development capacity (9).

The myofibers themselves are also at risk of death due to the oxidative stress that is produced in the mitochondria of these cells. Generally, mitochondria are repaired or removed by the cell's own protective mechanisms. However, with aging, this mechanism becomes less effective and the damaged mitochondria have the potential to kill the myofiber entirely (10).



Major neural changes take place as well. The motor cortex of the brain contains the neurons that control all skeletal muscle cells of the body. A motor unit is defined as a single neuron and all the muscle cells it innervates, ranging anywhere from 30 myofibers up to several hundred per neuron.

There are generally two types of motor units and their muscle cells have very different characteristics. Type I motor units contain muscle cells that are small, contract slowly, and resist fatigue very well. These muscle cells are effective in activities that require endurance, such as walking or standing, but they do not produce much not much contractile force or power. Type II motor units contain muscle cells that are larger, contract rapidly, and fatigue quickly. Type II muscle cells are effective in activities that require strength and power, such as playing sports, lifting heavy

objects or recovering from a stumble. Active agers rely on their Type II fibers to help them live their lives to the fullest. The problem is that the aging process leads to Type II motor units decreasing in mass and myelination which results in less muscle fibers being recruited and at a slower contraction velocity (11). As Type II motor axons are lost, surviving Type I motor axons will “rescue” some nearby Type II fibers by sprouting collateral axon fibers to re-establish innervation. However, this leads to Type II myofibers taking on slower and less forceful characteristics of Type I myofibers which, although useful for endurance activities, reduce the ability for muscles to generate muscle power and reduce the balance recovery capability (9,11). This results in DYNAPENIA, which refers to an older adult losing the capacity to move forcefully and powerfully, and has been shown to be more highly correlated to loss of physical function with age than sarcopenia (12).

Fortunately, active agers oftentimes have muscle mass and muscle quality very similar to that of middle-aged persons. The illustration below demonstrates this by showing that the thigh muscle mass of an active 70-year old is quite similar to that of a middle-aged active person. However, small durations of de-training due to injury, illness or other curveballs life may throw at an active ager can lead to rapid losses in both muscle mass and muscle function. In fact, older adults lose muscle mass and function on a much faster time course than young and middle-aged adults. Only 2 weeks of inactivity will result in significant losses and all training gains can be lost within 1 month of inactivity (12, 13). This means that an active ager must be ALWAYS ACTIVE – because even a short break in their activity can have serious consequences on the neuromuscular system.



Additionally, spinal reflex pathways become dysfunctional with age, although slightly less so with active agers. Reciprocal inhibition, commonly seen in functional tasks such as walking, pulling, and pushing, is a reflex where antagonist muscles relax as the opposing agonist muscles contract. The opposite reflex, co-activation, sees both the agonist and antagonist muscles contract together and is typically associated with situations where extra strength or stability is needed, such as heavy lifting or staying upright when on an unstable surface (e.g., skiing). Older adults show decreases in reciprocal inhibition and increases in co-activation during movement, which can be problematic and lead to soft tissue injuries and/or falls (11).

Age-Related Changes to Cardiopulmonary and Metabolic Function

The heart is the most important muscle in the body, contracting millions of times over an average lifetime to deliver oxygen-rich blood to the tissues of

the body. As with skeletal muscle, there are changes that take place in the heart that affects its performance in the later years. Collagen, the rigid connective tissue, increases throughout the heart and decreases the ability for the heart to expand and fill to the same degree as earlier in life. This decreases maximal stroke volume, a critical component of cardiac output, the amount of blood (and therefore oxygen) that can be pumped out per minute. The decrease in stroke volume is much less in active agers due to a larger ventricular chamber size and greater blood volume than their sedentary peers and therefore have higher aerobic capacity (VO_2 max), a measure of metabolic fitness (12). According to research by the prominent exercise physiologist Steven Blair, VO_2 max has a stronger protective effect on disease and death than most other physical characteristics, including body weight and body fatness (14). This emphasizes the importance of maintaining or increasing metabolic fitness in active older adults. In 2006, the Journal of the American Medical Association published the results of a 9-month study involving 3,075 older adults, aged 70 to 79, performing a long-distance (400 meter) corridor walking test and found that each additional minute of time over the average time taken to complete the walk was associated with a 29% risk for death and a 20% increased risk for a cardiovascular incident, and a 52% increased risk for a movement impairment (15). Another research study from the Cooper Institute demonstrated that if a 75-year old is able to walk/run a mile in 17 minutes or less, there is an 84% chance of survival to the age of 90 (16)!



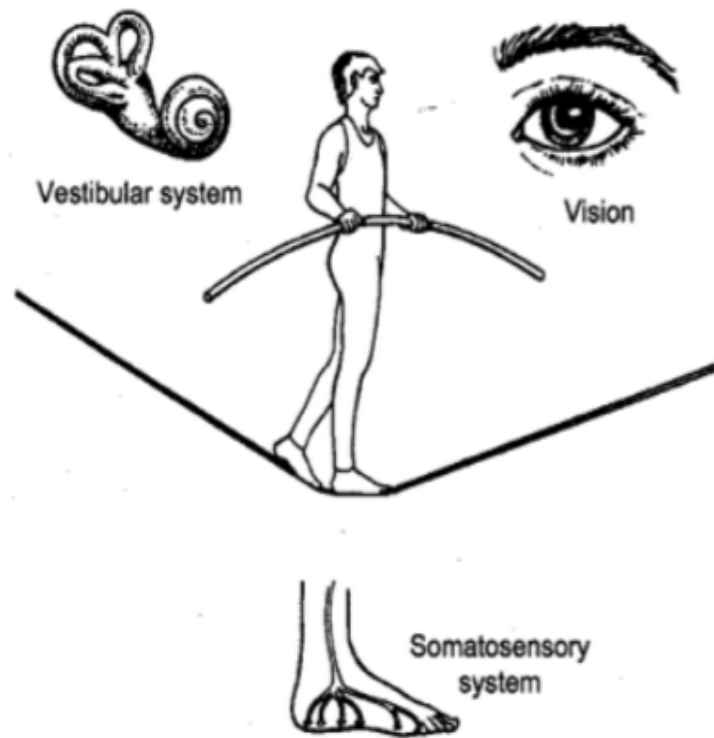
The aging process also causes structural changes in the arterial wall which reduces its elasticity and compliance and therefore increases blood pressure in older adults. However, your active older clients typically show less of this arterial stiffness due to the protective effect of past and current physical activity and often have lower blood pressure than their sedentary peers (17). This is a good thing because hypertension is a strong predictor of both CVD and stroke.

There are some other cardiopulmonary parameters that lose function with age, regardless of physical activity levels. Maximal heart rate decreases due to reductions in pacemaker cells within the sinoatrial node of the heart. Alveoli in the lungs, responsible for gas exchange between the lungs and the blood, decrease in number. However, these changes are typically not a serious threat to the physical performance of an active older adult. In some cases, active older adults may actually be at risk for more cardiovascular problems with age, particularly with irregular heart rhythms. Atrial fibrillation, an abnormal contraction of the upper chambers of the heart, is

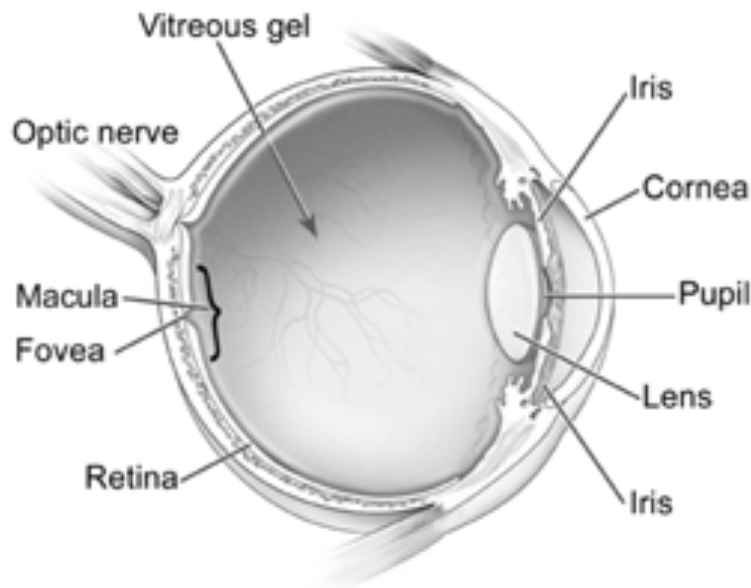
related to poor lifestyle behaviors in many sedentary older adults but also is related to active aging due to heart muscle damage from the accumulation of stress on the heart from long-term participation in strenuous activities such as marathons and triathlons (18). Management of active agers with atrial fibrillation will be discussed later in this course.

Age-Related Changes to the Sensory Systems

The body's sensory systems, including vision, hearing and balance control do not function as well in the later years of life, even in active agers. These systems need to be accounted for during training, and some can improve with exercise training (19,20).



The human eye, vital to a well-functioning visual system, deteriorates after the age of 40 in an accelerating fashion. These changes include thickening of the cornea (the outer clear protective layer of the eye), a decrease in the ability to dilate the pupil, stiffening and clouding of the lens, and loss of rods and cones on the retina. These issues affect vision, particularly in low light conditions and when bright lights are in the field of vision, which explains why many older adults have concerns about driving automobiles at night. Additionally, common eye pathologies such as cataracts, glaucoma and macular degeneration can cause serious visual issues and affect function and increase fall risk tremendously.



According to the National Eye Institute, older adults are at elevated risk for many eye diseases compared to younger people (21). The most common pathologies include cataracts, macular degeneration, and glaucoma. Cataracts occur when proteins within the lens of the eye becomes clumped together leading to a cloudy lens that results in blurred and darkened vision. Macular degeneration affects the retina of the eye where the sensory cells (i.e., rod and cones) are destroyed, particularly in the center of the retina, an area known as the macula. This causes vision loss, often in the center of the visual field. Glaucoma is caused by increased pressure within the eye, often associated with systemic hypertension. This increased pressure reduces blood flow to the retina and damages the sensory cells there.

Vision undergoes substantial changes in the later years and, although most older adults will never become fully impaired, the vast majority of people

over the age of 65 years require the use of corrective lenses (21). The primary changes to vision include:

- Decreases in visual acuity: The ability to see things clearly peaks for most people in their late teens or early twenties. At this point in time, it is not unusual to find many people who have 20/20 vision (the ability for a person to clearly see an object at 20 feet that others with normal vision can also clearly see at 20 feet). By the time a person reaches the age of 65, it is more likely that visual acuity will be 20/70 (the person will clearly see an object at 20 feet that others with normal vision would be able to clearly see at 70 feet).
- Farsightedness: Also known as presbyopia, this is an inability to see close objects or small print and it progressively occurs in all persons as they age. Farsightedness is due to a decrease in the flexibility of the lens of the eye and causes the focal point for vision to move farther away from the eye. In order to compensate, one must wear either reading glasses, or, in the case of visual acuity issues also being present, wear bifocals.
- Changes in color perception: As the lens of the eye becomes more rigid and less clear, people begin to have difficulty distinguishing colors that look similar to one another (particularly blue/green/violet colors). Additionally, a person may comment that even bright colors seem somewhat faded.
- Increased time to adjust to changing light conditions: Also known as senile miosis, this condition is caused by a yellowing of the lens of the eye and therefore less light reaches the retina of the eye. This results in a person requiring more time to adjust to changing light conditions and is a primary reason for older adults to choose to avoid

driving an automobile at night. It can also cause issues in brightly lit locations and may result in an increased amount of glare being sensed by the older adult.

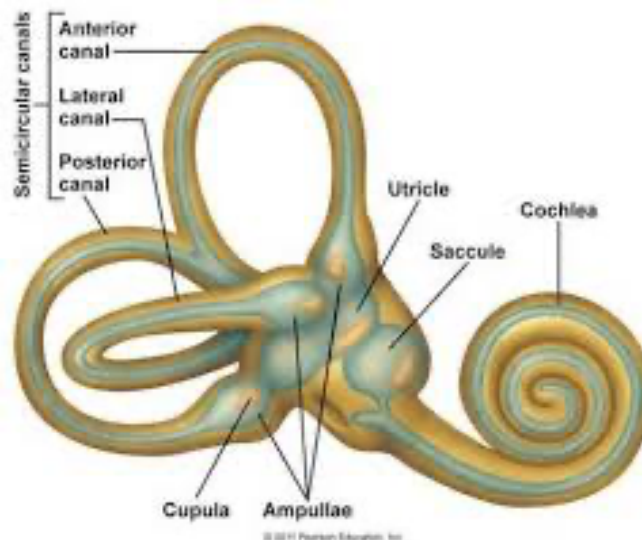
Sensory Impairments: Hearing

Hearing impairments are common in older adults. These can range from having issues with hearing certain frequencies of noise (e.g., loss of ability to hear very high-pitched noises such as a beep from a treadmill), to inability to hear sounds at low volume, to total deafness. Over 30% of people aged 65-74 have some degree of hearing loss, and that increases to over 50% in people aged over 75 (22). The effects of hearing loss may include difficulty in hearing high pitched tones, distortions in the ability to understand human speech, hearing ringing in the ear, and problems in hearing speech while in a noisy environment. Unfortunately, hearing loss is also a major contributor to both depression and dementia in older adults (22). The primary changes to hearing include:

- Conductive hearing losses: This results from when sound waves are not transmitted effectively from the outer ear to the inner ear. Amplification with hearing aids can improve this problem, but they also amplify unwanted noise coming from the surrounding environment.
- Sensorineural hearing losses: This is due to damage to the structures of the inner ear (i.e., cochlea and/or auditory nerve). This may cause extreme sensitivity to certain noises or cause a ringing or hissing sound to be heard. Hearing aids are not effective at treating sensorineural hearing losses.

Sensory Impairments: Vestibular System

The vestibular system, which consists of the fluid-filled structures of the inner ear, loses its sensitivity with age because cilia, the tiny hair-like projections that line the structures, are reduced in number and are affected by debris in the system. The loss of these hairs decreases the amount of stimulation to the vestibular nerve and causes the brain to have less incoming information of how the body is positioned. Additionally, blood flow decreases to the system due to circulatory changes. These changes lead to an increase in postural sway (oscillations in the center of gravity while standing) and balance issues during walking, particularly on variable surfaces. Recent research has indicated that the sensitivity of the vestibular system reduces by 50% every decade after the age of 40 (23).

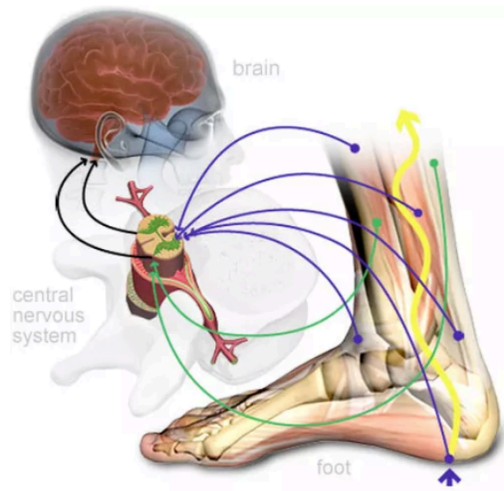


More significant vestibular dysfunction with aging includes vertigo and vestibular neuritis. Accumulation of calcium deposits (sometimes called

ear rocks or otoliths) can stimulate the cilia and caused vertigo, a condition where movement is sensed even when the body is stationary and leads to disorientation and nausea. Vertigo often requires medical treatment and regular performance of Epley head maneuvers to return to normal function. Vestibular neuritis is an inflammation of the vestibular nerve to the brain and is accompanied by similar symptoms.

Sensory Impairments: Somatosensory System

The somatosensory system refers to sensory receptors throughout the joints and nerve endings of the body. This important system in the feet and toes detects the type of surface where someone might be standing/walking. These receptors are sensitive to pressure and movement and inform the brain of the surface that the person is standing on. These receptors are particularly helpful when the surface is slippery, sloped or highly variable because it enables the person to adopt the most effective balance strategies to stay safe on any terrain. However, research has indicated that the foot is less sensitive to touch and texture with age and the joint structures of the lower body get stiffer with age due to an increase in the rigid connective tissue collagen. Both of these factors result in decreased sensory information relayed to the central nervous system and, in turn, affects the speed and quality of the movement responses to expected and unexpected challenges to balance (24).

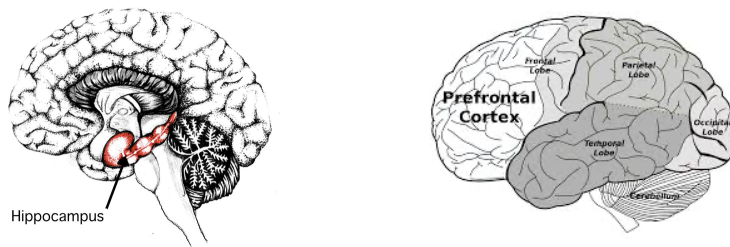


Several medical conditions have a major effect on the somatosensory system. Diabetes can cause peripheral neuropathy where the nerve endings in the feet and toes are affected by the destruction of the small blood vessels that nourish them. This leads to a permanent sensation of pain, numbness or tingling (known as paresthesia) which reduces the ability to determine the surface below the feet and greatly increases fall risk. Ataxia, a degenerative neurological condition affecting overall coordination, also can interfere with proper somatosensory function.

Cognitive Aging: Memory and Executive Function

Two major changes in cognition that occur with age include memory and executive function. Memory is modulated by the hippocampus, a deep portion of the brain, which networks with many other parts of the brain to bring information out of its storage location and into our conscious mind. Aging causes the hippocampus to decrease in size (and therefore neurons) by 2% per year after the age of 65 (25). Fortunately, research has shown

that cardiovascular exercise training has a beneficial effect on maintaining hippocampal volume in older adults (26).



Executive function, on the other hand, involves the prefrontal cortex of the brain and is responsible for a person's ability to maintain attention, ignore distractions, control emotional impulses, multitask, prioritize and set goals for daily successful function. Several forms of exercise have been found to positively affect executive function including cardiovascular training, high intensity training, resistance training and multimodal exercise programs (27). It has also been demonstrated that adding cognitive challenges into exercise training sessions may create an amplified improvement in fitness and cognitive adaptations (28).