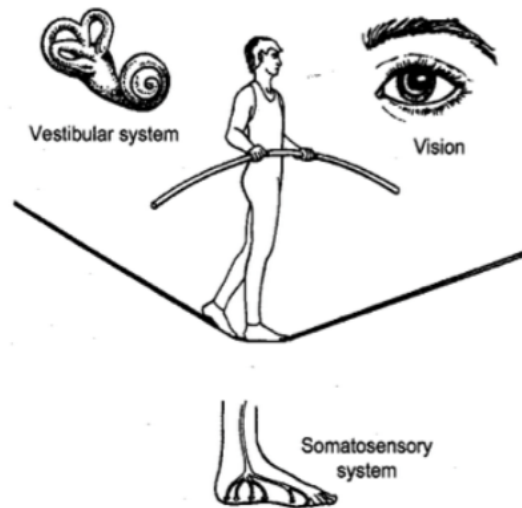


# The Complete Guide to Balance Training - Part 2 of 5

## Physiological Aging and Fall Risk

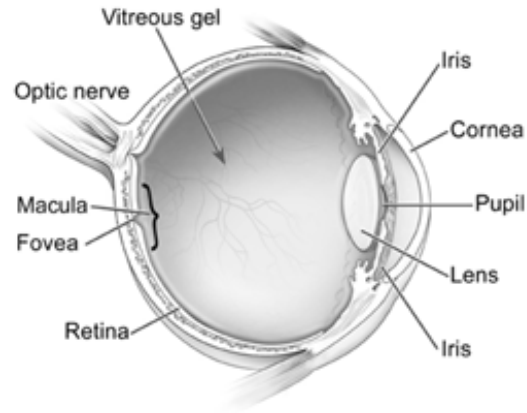
### Age-Related Changes to Sensory Functions

The body's three primary balance control mechanisms: the visual, vestibular and somatosensory systems are sensory systems that do not function as well in the later years, even in the absence of diagnosed disease (6,7,8).



The human eye, vital to a well-functioning visual system, experiences anatomical deterioration with age. 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 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 increase fall risk tremendously (7,8).



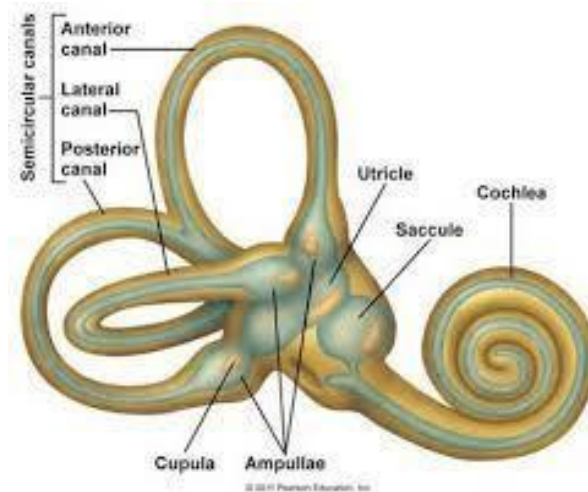
According to the National Eye Institute, older adults are at elevated risk for many eye diseases compared to younger people (7). The most common pathologies include cataracts, macular degeneration, and glaucoma.

Cataracts occur when proteins within the lens of the eye become 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.

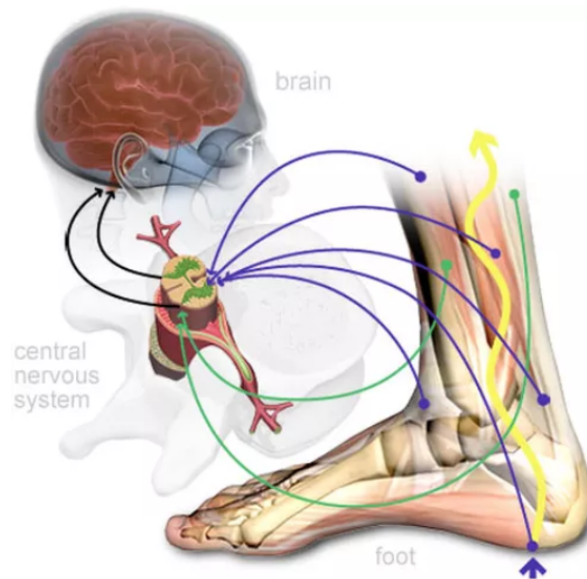
The vestibular system, which consists of the fluid-filled structures of the inner ear, loses its sensitivity with age because cilia, the tiny hair-like projections that line the structures, are reduced in number and are affected by debris in the system. The loss of these hairs decreases the amount of

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 age-related circulatory changes. These changes lead to an increase in postural sway (oscillations a person's center of pressure 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 (9).



More significant vestibular dysfunction with aging includes vertigo and vestibular neuritis. Accumulation of calcium deposits (sometimes called ear rocks) 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. The increase in fall risk seen with these conditions is dramatic.

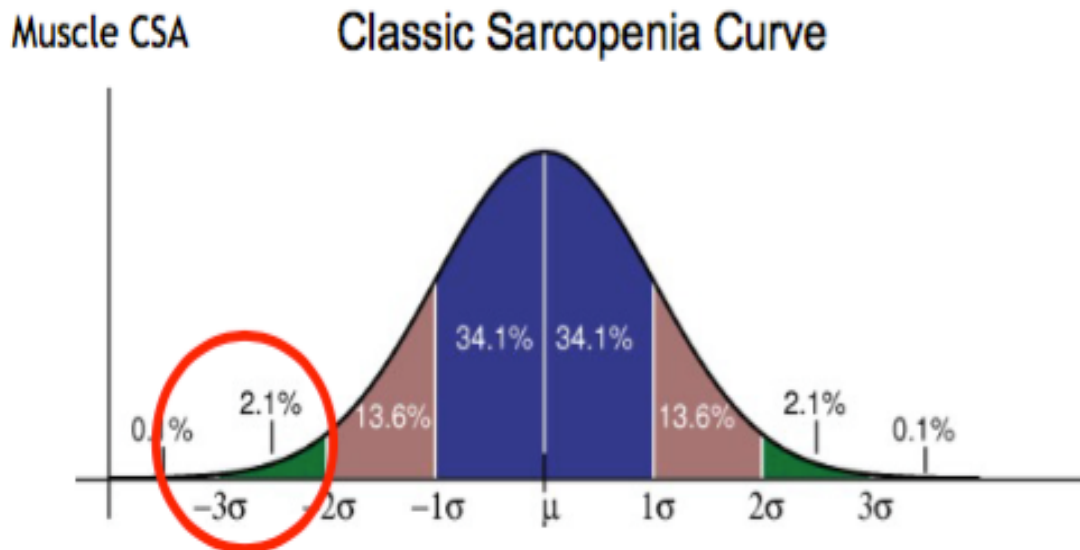
The somatosensory system refers to sensory nerve receptors throughout the skin, muscles, tendons and joints in the body. This important system in the feet and toes detects the type of surface where someone might be standing/walking and will also detect slope of the surface. These receptors are sensitive to pressure and movement and inform the brain of the environment so that the brain can coordinate the most appropriate motor response, an interaction termed sensorimotor integration. This process is 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 (10).



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. Parkinson's Disease (and related disorders), a degenerative neurological condition affecting overall coordination, also can interfere with proper sensorimotor integration.

### Age-Related Changes to Muscle Function and Gait

Other bodily systems related to falls risk decline with age, particularly in



those that are not regularly active. Of major importance, the neuromusculoskeletal system undergoes substantial reorganization and atrophy. 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 (11). This is a concern because there is a relationship between amount of muscle protein within myofibers and the ability for myofibers to produce force and power. With sarcopenia, independent living is threatened due to muscle mass reaching this critically low level.

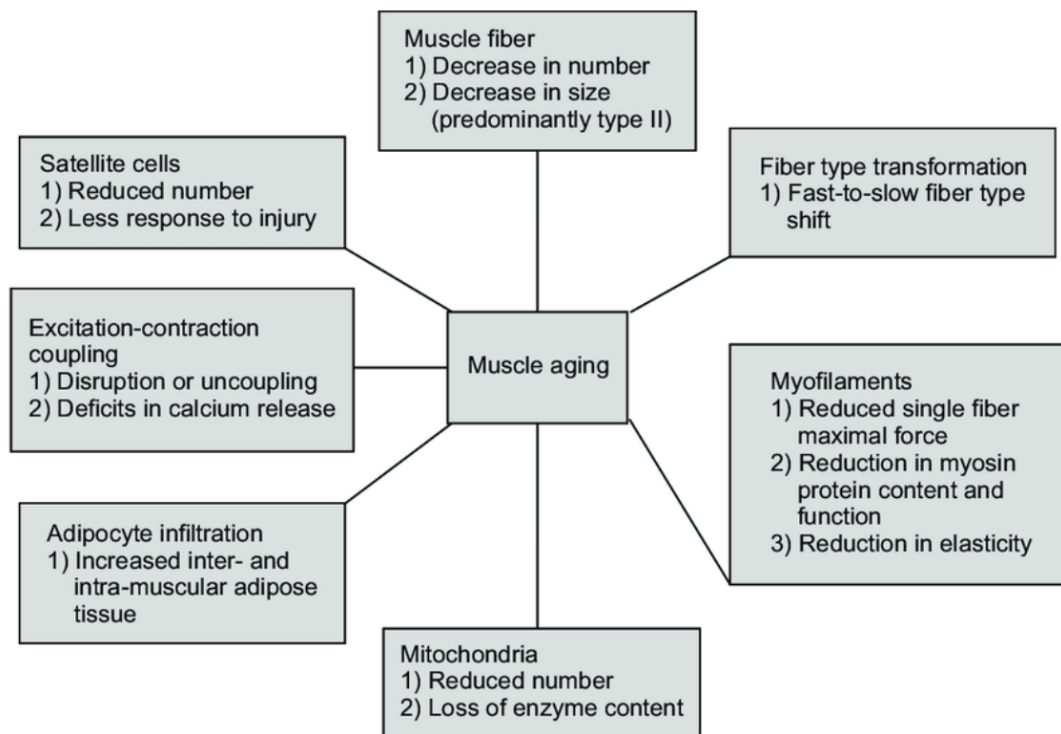
During young and middle age, muscle function (i.e., strength and power) is strongly correlated with the amount of muscle mass a person has accrued. However, this relationship becomes less correlated with age. Many older adults without diagnosed sarcopenia experience major losses of muscle

strength and muscle power, often to the point of a loss of independence due to losses in walking speed and lifting capacity (12). Even though muscle mass atrophy may not reach the level of diagnosed sarcopenia, there is often a loss of muscle quality, where fat and connective tissues replace contractile proteins. 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 (13).

Major neuromuscular 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 force or power. Type II motor units contain muscle cells that are larger, produce high amounts of force, contract rapidly, and fatigue quickly. Type II muscle cells are effective in activities that require strength and power, such as lifting heavy objects, playing sports or recovering from a trip or stumble. From a function standpoint, older adults need both Type I and Type II fibers to work well. 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

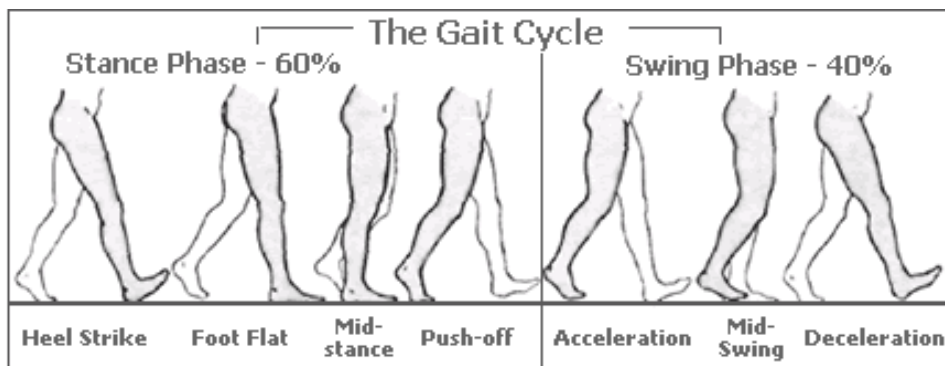
slower contraction velocity (14). As Type II motor axons are lost, surviving Type I motor axons will “rescue” some nearby Type II fibers by sprouting collateral axon fibers to re-establish innervation. However, this leads to Type II myofibers taking on slower and less forceful characteristics of Type I myofibers which, although useful for endurance activities, reduce the ability for muscles to generate muscle power and reduce the balance recovery capability (11,12,14). This results in older adults losing the capacity to move forcefully and powerfully, which puts them at greater risk for fall due to the loss of the ability to recover from trips and stumbles. This loss of muscle power, termed dynapenia, has been shown to have a greater negative effect on quality of life and acute injuries than sarcopenia (12).



Lastly, spinal reflex pathways become dysfunctional with age. Reciprocal inhibition is a reflex where antagonist muscles relax as agonist muscles reflexively contract and is commonly seen in functional tasks such as walking. The opposite reflex, co-activation, is a reflex when both the agonist and antagonist muscles contract together and is typically only needed in situations where extra stability is needed, such as trying to stay upright when standing on a rocking boat. Older adults decrease reciprocal inhibition and increase co-activation during walking, possibly trying to increase joint stability and decrease fall risk, but it inhibits the ability to generate power and reduces an older adult's ability to successfully recover from a slip or stumble (11,12,14).

### Age-Related Changes to Gait

Gait is categorized into two phases: the stance phase and the swing phase. The stance phase occurs when the foot is on the ground. In young to middle-aged adults, the stance phase makes up 60% of the gait cycle. The remaining 40% of the cycle is spent in the swing phase where the foot is off the ground and being propelled forward.



By the age of 80 years, over 50% of older adults have an abnormal gait patterns due to the aging process. The alterations include decreases in stride length, stride time, and gait velocity (15). Older adults also tend to walk with a widened stance to compensate for a perceived lack of balance. This gives the walking pattern an appearance of a waddling duck with increased side-to-side motion and less natural rotation of the upper and lower body. These gait changes may give older adults a sense of security while walking but they actually put them at greater risk for falls due to faulty biomechanics (15).

When trips or stumbles occur, the body is propelled forward. In order to recover, the stance foot must keep its position so that the recovery foot can quickly swing forward to regain a stable position. Research has determined that there is a strong correlation between muscle power and ability to use this gait strategy to recover from tripping (11). It is clear that exercises for both muscle strength/power and gait training strategies must be a part of a successful fall prevention exercise program.

### Age-Related Changes in Cognition

Additionally, cognitive changes with age, even in the absence of a diagnosed dementia, can reduce attention, awareness and judgement which increases risk of falls when an older adult is walking with divided attention to gait and other tasks, such as talking, looking around, or carrying items (16, 17).

