How Balance Works

Balance is the ability to maintain an upright position. Coordination is the capacity to move through a complex set of movements while maintaining balance. Balance and coordination depend on the interaction of multiple systems working together. The primary systems including the vestibular system (inner ear), visual (movements of the eyes), and proprioception (commonly referred to as your touch and feel sense). The central nervous system, primarily the brain stem and cerebellum, provides the central processing for the three sensory input systems into one coordinated event, allowing for one output of responses, balanced and coordinated.

The vestibular system (Inner ear) is also called the labyrinth, which monitors our directions of motions during: turning, moving forward-backward, side-to-side, and up-and-down. The inner ear contains two individual organs for balance:
(1) the utricle, made up of macula and saccule and (2) a set of three semicircular canals.

The organs of the utricle are responsible for the sensation of gravity. The maculae and saccule are made of delicate nerve endings that are connected to a structure made of calcium carbonate. These particles have a greater density relative to the fluid that they are immersed in, causing them to "fall" because of the action of gravity. As the head moves in relation to gravity the particles exert pressure on the nerve endings (the best example of this is feeling the acceleration and deceleration in an elevator). The macula and saccule are roughly at right angles to each other and give slightly different positional information. In this way the utricle of the inner ear is able to provide the brain with information about the position of the head relative to gravity.

Information on head rotation is provided by the semicircular canals. There are three semicircular canals in each ear: superior, horizontal, and posterior. They are roughly at right angles to one another; each one corresponding to one dimension in a three dimensional space. The canals are filled with a fluid. As the head turns, the fluid rotates within the canal and moves hair cells connected to nerve endings within one end of the canal. Fluid within the canals always moves in the opposite direction in each ear; the best way to explain this is, our ears are on either side of our head and if we turn our head, one ear goes forward and the other backward. This holds true with the fluid in the ear, it always moves in the opposite direction and the brain understands these signals as a coordinated movement. The nerve endings within the canals then send information back to the brain about how quickly and in what direction the head is moving. Try this, close your eyes and move your head a very tiny, tiny bit; almost keeping your head still and you should be able to sense even the very smallest of movement with your three semicircular canals in any direction. This is a very delectate system.

The visual system or eyes monitor where the body is in space (i.e. upside down, right-side up, etc.) and also the directions of motion. Vision provides necessary information to the brain about our relationship to the environment. As we move and see how objects in our world are changing, our brains calculate our body's relationship to those objects. The best example of this is looking over a cliff; we feel as though we are falling, even though our bodies are stable. It is our eyes that are pulling us into our visual field; this is where our vestibular and proprioception systems try to over compensate the signals to the brain, telling us that we are not really falling into the open space. Additionally, there is an intricate communication between the vestibular system and the movements of the eyes, the vestibular-ocular reflex (VOR). The vestibular system works to control eye position and movement so that when your head moves, your eyes can automatically stay fixed. VOR is easily explained; when you walk your head moves up and down, but your visual world stays

stable (unless your VOR is fails, in which case you have oscillopsia or bouncy vision). Because of the vestibular-visual link, vestibular system problems can also cause fuzzy vision, nystagmus (abnormal eye jerking), and other visual sensations.

The proprioceptive system, or skin pressure & muscle and joint sensory receptors, such as in the joints and spine, tell what part of the body is down and touching the ground as well as what parts of the body are moving. Humans seem to rely primarily on signals from the pressure sensors in the legs and torso (proprioceptors) to maintain good balance, more than other animals with four legs (who have four inputs) or fish that rely almost solely on their vestibular sense. Proprioceptors are essentially billions of messenger nerves located in the skin, muscles, tendons and virtually everywhere. These messengers send signals to the both the vestibular system as well as the brain to process our environment. This portion of our proprioceptive systems that communicates with our vestibular system to maintain balance by controlling the muscles of postural control is the vestibular spinal reflex (VSR).

Balance
As seen above, the three primary balance systems: vestibular, visual, and proprioception individually send signals to each other as well as the brain about head and body movements relative to gravity and rotational movements. In most individuals, the brain selects the most accurate signals from a combination of the three balance systems; which in theory should be the same information and signals. As the brain interrupts these three input senses, it generates one specific message that is sent back to the muscles of the limbs, torso, neck and eyes to keep us stable and upright. The more signals the brain receives and sends (in milliseconds), the better our balance. If one of the systems is damaged or affected in any way, the other systems must compensate to keep us balanced. Temporary loss of one of these systems can result in any period time can create instability. For example: changes in signals from a damaged inner ear vestibular system (ex. A concussion) can result in a sensation of dizziness; or a visual problem that causes blurring or double vision may cause a sensation of unsteadiness or disequilibrium, and variations in proprioception are seen after an injury, involving either as sprained or torn ligaments that changes your body's awareness in three dimensional space. As stated, the signals that the brain receives or sends can be disturbed by changes or fluctuations in these systems, making it difficult to balance or stay coordinate during even daily activities. This is why is may be necessary to get a complete evaluation with specific testing for your vestibular, visual, and proprioception systems to determine the exact cause of your common symptoms and to determine an objective treatment course.

Hearing and Balance
The hearing and balance organs are connected to each other within the inner ear. This same inner ear fluid also fills the balance canals, so that when you move your head, this fluid flows back and forth, activating a nerve signal that is carried over the balance nerve to the brain. So long as the ear works in this way, we are able to experience normal hearing and balance. Because they are connected, about 30% of profoundly deaf persons are estimated to have vestibular (inner ear balance) problems. Hard of hearing persons may also have vestibular problems. Some of the signs of impaired vestibular function can include: infants who cannot sit unsupported by 6-7 months; infants who are not walking by 15 months; clumsiness; difficulty walking on uneven surfaces; poor balance in darkness; difficulty riding a bicycle; disorientation when swimming with eyes closed; and difficulty keeping a stable view of the world when you are jogging or riding in a car over a bumpy road.

Improving Balance - To help overcome balance problems due to impaired vestibular function, the brain needs to receive additional information from the visual and proprioceptive systems while the vestibular system is being stabilized. The more signals the

brain receives from the two remaining systems, the better your balance will be. Some suggestions for improving signal strength and interaction from vision and proprioception (muscles) systems:

- Use your eyes as much as possible.
- Place nightlights in bedrooms, halls, and bathrooms.
- Train your leg muscles and increase signals from both the legs and feet by walking barefoot on a variety of uneven surfaces (grass, sand, trails, hills, etc.).
- Practice sitting on a narrow beam with your feet dangling in the air. This helps your hips and upper body to help the legs to maintain balance. Again, use a partner.
- Swim with the eyes open, wearing goggles if necessary.
- Increase your muscle strength with exercise and sports (Wear good, stable, flat laced shoes).
- Do balance exercises. Stand on one leg with eyes open and closed. Try to walk on a straight line (Practice with a friend to prevent falling).

When it is dark, use a flashlight. The reasons are obvious: we cannot see very well in the dark, so the brain only receives signals from the muscles; this makes the person unstable. It is apparent that the brain has an incredible capacity to improve balance by finding new pathways and developing new strategies when one or two of the systems are impaired and why some patients benefit from balance therapy and rehabilitation.