Proprioceptors and Human Balance
Stanly Granger, Exercise Science
Dr. William Simpson, Health and Human Performance Dept.
**ABSTRACT**

*Human balance consists of proprioception in three different components; the vestibular component, the visual component and the body receptor component.* All three components working together help the body to stay functioning at a high level. *This experiment involves the stimulation of each of the components of balance and comparing the results with a control set of data consisting of non-stimulated balance results. The objective of this study was to confirm the negative effects of stimulating the vestibular and visual components and also to examine the effect of stimulating the receptors in the soles of the feet. The results showed the negative effects of vestibular and visual stimulation and also show positive effects of feet stimulation. This work suggested that stimulation of the receptors located throughout the human body may be beneficial to human balance.*

**Introduction**

It can be argued that balance is the key to life. Balance would not drastically affect the quantity of life, but certainly the quality of life. Consider the early stages of life when an infant begins to crawl and eventually takes that first step. Balance is the key component to these critical early phases of life. As balance develops, the bodies activities also develop, these activities deepen and become more complex. Patterns of
movement are seen and imitated, movement with objects and movement with other people takes place, all of which are signs that motor learning is taking place. Balance is critical in these phases. Throughout life, from beginning to end, balance plays a key role in living life at its fullest. In fact, as the years of life begin to add up, the quality of life can be drastically decreased due to balance shortcomings. For the older generation, losing their balance and falling often has dramatic, life altering consequences. Hospitalization followed by lengthy and often permanent nursing home stays are common after significant falls. Among the older generation balance certainly would affect the quantity of life as falling deaths are most common among the elderly. Balance is an internal mechanism that supports motor movement as well as structural solidity.

There are three components to human balance. These three components are all working to detect and send information to the brain about where the body is in relation to the rest of the world (The Nemours Foundation, 2012). This detection in relation to the world is commonly known as proprioception. These three balance components consist of proprioception of the vestibular system in the inner ear, proprioception from focal and peripheral vision of the eyes and the proprioception from the receptors in the neck, torso, legs and, most importantly, on the feet. A loss of any of these
components would naturally result in a decrease in overall balance; however, can these components of balance be enhanced? And, if so, can the enhancements lead to an increase in balance? There are countless rotational exercises and eye exercises that can certainly help balance by developing inner ear patterns, stimulating peripheral sight and fine tuning minute motor movement; however, these exercises involve a series of activities that, over time, may lead to increased human balance. Can it be simplified? Can balance be enhanced with simple stimulation? It may be possible to vigorously brush the soles of the feet to essentially “wake up” the receptors in the feet and increase balance and, subsequently, human performance.

**Ear-Hearing and Proprioception**

Perhaps the most recognized component of balance is the inner ear. People recognize it because they have experienced what happens when the inner ear is stimulated. We have all made ourselves dizzy and stumbled about as the world spins around us. Conditions such as vertigo, dizziness, motion sickness, disequilibrium are all conditions that arise when the vestibular system has been stimulated or even compromised (Balance Disorders, 2012).

The ear is a critical organ in the conditions of daily living. Certainly, the ear is responsible for the body’s sense of hearing, the cone shape of the outer
ear alone tells that story. Sound waves are caught by the outer ear and
funneled down to the inner membrane which vibrates as sound waves disturb
it. Those vibrations are sent to the cochlea and organ of corti which
translates the sound waves pitch and loudness and pass the information on to
the brain through the vestibulocochlear nerve (cranial nerve VIII). But the
inner ear or the vestibular portion of the ear is also a crucial part of life and
this part of the ear is where the component of balance lies. The inner ear
consists of three semi-circular canals. The anterior canal and the posterior
canals sit at right angles to each other and are essentially vertical when a
person’s head is erect (CNS Clinic-Jordan, 2007). The lateral canal is
almost horizontal and sits on a plane perpendicular to the anterior and
posterior canals and it is the arrangement of these canals that provides the
vestibular system the capability of detecting head movement in all directions
(CNS Clinic-Jordan, 2007). These canals are connected at both ends to a
large sac filled with fluid called the utriculus; however, one end of the canal
is enlarged and is known as the ampulla. In this enlarged portion of the
canals a flexible mechanosensitive barrier called the crista ampullaris keeps
fluid from freely flowing through the canals and into the utriculus (CNS
Clinic-Jordan, 2007). The utriculus is connected to another sac called the
sacculus. Located within the utriculus and the sacculus are structures called
macula acustica. The crista and the macula are in neural contact with the central nervous system and act as the proprioceptive units in the inner ear (CNS Clinic-Jordan, 2007). The canals contains hair cells which act as detectors during head movement. These hair cells project into a mass known as the cupola that sits across the ampulla(s). The crista ampullaris is a thin membrane between the semi-circular canals and the utriculus. The fluid within the utriculus and the semi-circular canal flows in one direction or another as the head goes through its many angular movements. These flexible barriers bulge and push against the hair cell within the cupola which produces impulses to keep the central nervous system aware of the movements of the head (CNS Clinic-Jordan, 2007). The macula acustica(s) act as detectors that respond to gravitational pull as well as acceleration and deceleration. These macula are also known as otolith receptors because the hair cells associated with these detectors project into structures impregnated with dense calcareous formations called otoliths (CNS Clinic-Jordan, 2007).

**Eye-Vision and Proprioception**

The eyes are another key organ in everyday life. Humans are almost completely controlled by vision as nearly 70% of the sensory receptors in the body can be found in the eye (Marieb & Hoehn, 2010). It is understandable from this information that vision is the body’s dominant
sense and humans must be specially trained to learn to react to input from the other senses. The human eye receives light from the world around us. Different wavelengths of light are absorbed or reflected by every object and the wavelength being reflected from the object determines the color of each object. Light is allowed to enter the eye by the pupil and is focused onto the retina by the lens. The eye has roughly 250 million photoreceptor cells that are located on the retina in the back of the eye (Marieb & Hoehn, 2010). These photoreceptor cells become excited in the light and send information to the brain. The brain interprets the signals of light and creates visual images (Balance Disorders, 2012).

There are two types of photoreceptor cells; rods are more numerous and are active in dim lighted situations and act as peripheral vision receptors, and cones operate in bright light and are active in focal vision and provide high acuity color vision (Marieb & Hoehn, 2010). Each eye will receive slightly different images of the same object being viewed by the eyes and these different images along with other information being received by the eyes are interpreted by the brain and are key in determining direction and depth and are a vital part of balance (Balance Disorders, 2012). The system of the eyes working as a team is referred to as binocular vision. The peripheral vision also makes use of the background data to determine normal and the horizon
line to determine level. The processes of focal vision and of peripheral vision working together are critical in the ability for the body to organize itself in space during movement. Any distortions in the system will cause a misperception in the body’s position in space (Politzer, 2012). Essentially, the body will think itself in one place when it is actually in another. This may cause dizziness and balance problems as an individual may have a tendency to lean to one side or forward and backward.

**Body – Touch, Feel and Proprioception**

The third component of balance is the human body itself. The human body as an entire unit is composed of cells, tissues, organs and systems all working together to provide the body with what is needed to sustain life. In order to keep itself out of harm’s way, the human body must be aware of itself at all times. One hand must know what the other is doing. This self-awareness is known as proprioception. This self-awareness is made possible by countless receptors located throughout the body that detect external influences and stimuli from the external environment and from within the body and sends this sensory information to the central nervous system. These receptors send information that deals with force, rate, direction and range of movement and also send signals that respond to touch, pressure, temperature and pain (Tantorski, 2007).
The specific receptors in the body that pertain to balance are located on the neck, torso, legs and most importantly the foot. These receptors are divided into two categories: conscious and unconscious. The conscious receptors are mainly located in the joint capsules, tendons and ligaments and are responsible for the body’s ability to perceive and recognize self-movement. This self-awareness or proprioception allows for the regulation and monitoring of movement and posture. This proprioception is crucial in motor planning and motor learning (Tantorski, 2007). The unconscious receptors are found in the skeletal muscles. These receptors also carry information that deals with force, rate, direction and range of movement but this information is not received by the higher cortical centers of the central nervous system. This information often leads to a reflexive response which is why it is considered unconscious.

These receptors are highly developed and are a critical component in human balance. These receptors are very adaptable and are very discriminate with the ability to differentiate between deep and light touch as well as full or partial touch. Additionally, these receptors have the ability to determine precisely where the body is being touched and to some extent can determine temperature of the object touching the body (Tantorski, 2007).
and pass information that keeps the body aware of where it is and what it is doing at every second of every day. The body makes countless subtle, unconscious corrections in posture and movement throughout the day in an effort to keep the human unit upright and relatively safe at all times.

**Interaction Between the Components of Balance**

While each component of balance plays, in and of itself, a role in balance, the three components also cooperate to achieve the highest level of balance possible. Consider the relationship between the vestibular system of the ear and the extraocular muscles of the eye. As the head is slowly turned right or left, the eye muscles move the eye equally in the opposite direction to allow the eye to maintain a reference point even while the head is moved through different planes (CNS Clinic-Jordan, 2007). The vestibular system responds primarily to movement of the head but it can also regulate neuron activity in the spinal cord by which it can produce far reaching postural changes in the body. Activity in the peripheral receptors of muscles, tendons and joints can be influenced by the vestibular system and vice versa (CNS Clinic-Jordan, 2007). This interaction allows the body as a whole to overcome minor deficiencies in one component or another and keep the body balanced during these times; however, the interaction between these components can also cause disruptions in the balance system. Motion
sickness is caused by a disagreement between the vestibular system and the vision system. The vestibular system is detecting movement but the eyes are not seeing the same stimulus (Balance Disorders, 2012). Ever been sitting at a stop light and have the eyes detect movement from the car beside you? The reaction is to stomp on the brake as the perception is that your car is drifting backward. The vestibular system knows better, but the vision dominant body responded to what the eye saw and reacted incorrectly.

**Experiment-Set-up and Procedure**

This experiment went through a full review by the UWS institutional review board (IRB) as it involved, not only, experimenting and collecting data from students at UWS but also from individuals under the age of eighteen. The research proposal was submitted and approved by the IRB and each participant was given a consent form to be signed by the participant or the participant’s parents. All subjects were kept anonymous and data collected was also displayed anonymously.

The experimental portion of this research project consisted of a forty foot long balance beam, a foot brush, a spinning office chair and a special set of goggles. Two separate sets of volunteers were asked to walk a balance beam without stimulation and then walk the same beam after each component of balance was stimulated. The balance beam was constructed out of lumber
consisting of a 2” x 12” base lying flat on the floor with a 2” x 6” attached flat to the base to act as the balance beam itself. The length of each 2” x 6” was 2’ longer than the 2” x 12” base to allow for stability. The base lumber and the beam lumber were attached with 2 ½” torx screws, installed 2 screws per foot, and counter-set below the surface of the beam plate.

The beam was built flat on the floor in an effort to eliminate the fear of falling. Each individual was essentially walking on the floor and not on a beam suspended off of the floor. Eliminating the fear of falling allowed the subject to perform, as close as possible, the natural act of walking or running. Each participant was given instructions to stand at the front of the balance beam starting with one foot up on the beam and was instructed to walk or run the balance beam as fast as they could without falling. If the subject fell completely off of the beam the trial was marked as a fail and the subject was asked to restart. If the participant slipped off the beam with one foot, but corrected and kept going the trial was also marked as a fail but the time was kept and a restart was not requested. These failure parameters were kept consistent for each trial.

The first two trials were performed without stimulation and were recorded to establish the control set of data for each individual. After the control trials were completed the first stimulation trial was performed. Each
individual was asked to remove their socks and shoes and rub a sanitizing lotion on the soles of the feet (to minimize spread of bacteria and to minimize possible odors). Both feet were then brushed briskly for approximately 10 seconds with a soft bristled brush. Brushing the soles of the foot was designed to stimulate the proprioceptors on the foot in an effort to “wake them up.” The subject then put their socks and shoes back on and were asked to run or walk the beam again. Again, each trial was timed and recorded. After the foot stimulation trial each subject was asked to run or walk the beam with the special goggles on. The goggles consisted of a normal pair of safety glasses that had been almost completely blacked out, the viewing area of the glasses were completely covered except for a tiny square left open. The altered glasses essentially eliminated the peripheral vision and allowed the subject to see only straight ahead. Each subject walked or ran the beam and the time was recorded. The last stimulation trial took place on the spinning office chair. Each subject sat in the chair and was spun around twenty times. This spinning trial was designed to stimulate the vestibular system in the ears. Again, each subject was asked to run or walk the beam and the times were recorded.

The first set of volunteers was taken from the student population at the University of Wisconsin-Superior with the exception of a 16-year old male
being included in this set of volunteers. This volunteer set consisted of 12 males and 8 females. Many of the subjects were NCAA Division III athletes and all of the subjects appeared to be in good to great physical condition. All but four subjects were between the ages of 20 and 30 and all of the subjects were between the ages of 16 and 40.

The second set of volunteers was taken from the student population at Marshall School in Duluth, MN. Permission from the parents of the 5th grade class was granted and the total set of 5th grade volunteers consisted of 14 females and 8 males. All of the subjects appeared to be in good physical condition and were all between the ages of 9-12.

All of the adult subjects performed the tests on the same day in succession. The children performed the tests over the span of two days. The female volunteers started the testing on the first day and completed it on the second day and the males started and completed the testing on the second day.

Hypothesis

Prior to setting up this experiment to test the effects of proprioception stimulation on human subjects it was prudent to look forward and ponder the expected results of the experiment. The average elapsed times of each
stimulation trial were to be compared with the average elapsed time of the control data to determine if stimulation would have an effect on balance. Any negative effect on balance was expected to slow down the walk across the beam and a positive effect on balance was expected to speed up the walk across the beam. Because of this preconception, it was necessary to have an expectation prior to beginning the experiment.

The average elapsed times for the adults were expected to be faster in all experiments than the childrens. Adults have finer tuned proprioceptors and can be expected to have better balance. Certainly, stimulating the eyes and the ears of all the human subjects can cause a negative effect on balance and expectations were that the test results would show a much slower time following stimulation of the eyes and ears. Stimulating the proprioceptors in the foot was expected to show a minor increase in elapsed time as the hope was that the brushing of the foot would cause the receptors to wake up a bit and, therefore, cause a slight balance improvement.
## Experiment Results

### Marshall School 5th Grade Student Results

<table>
<thead>
<tr>
<th>Names</th>
<th>Control 1</th>
<th>Control 2</th>
<th>Avg</th>
<th>Stim 1</th>
<th>Stim 2</th>
<th>Avg</th>
<th>Dizzy</th>
<th>Eye</th>
<th>5th Grade Student</th>
</tr>
</thead>
<tbody>
<tr>
<td>C1</td>
<td>4.61</td>
<td>3.74</td>
<td>4.175</td>
<td>3.91</td>
<td>3.27</td>
<td>3.59</td>
<td>8</td>
<td>4.51</td>
<td>5th Grade Student</td>
</tr>
<tr>
<td>C2</td>
<td>5.72</td>
<td>5.87</td>
<td>5.795</td>
<td>5.19</td>
<td>4.26</td>
<td>4.725</td>
<td>6.68</td>
<td>5.56</td>
<td>5th Grade Student</td>
</tr>
<tr>
<td>C3</td>
<td>5.08</td>
<td>4.21</td>
<td>4.645</td>
<td>3.71</td>
<td>3.45</td>
<td>3.58</td>
<td>5.42</td>
<td>4.82</td>
<td>5th Grade Student</td>
</tr>
<tr>
<td>C4</td>
<td>6.5</td>
<td>6.68</td>
<td>6.59</td>
<td>6</td>
<td>5.46</td>
<td>5.73</td>
<td>20.43</td>
<td>7.06</td>
<td>5th Grade Student</td>
</tr>
<tr>
<td>C5</td>
<td>4.42</td>
<td>4.17</td>
<td>4.295</td>
<td>3.34</td>
<td>3.46</td>
<td>3.4</td>
<td>5.25</td>
<td>3.74</td>
<td>5th Grade Student</td>
</tr>
<tr>
<td>C6</td>
<td>4.34</td>
<td>4.07</td>
<td>4.205</td>
<td>3.46</td>
<td>3.31</td>
<td>3.385</td>
<td>8.14</td>
<td>3.75</td>
<td>5th Grade Student</td>
</tr>
<tr>
<td>C7</td>
<td>4.82</td>
<td>4.36</td>
<td>4.59</td>
<td>3.46</td>
<td>3.49</td>
<td>3.475</td>
<td>4.57</td>
<td>5.64</td>
<td>5th Grade Student</td>
</tr>
<tr>
<td>C8</td>
<td>4.45</td>
<td>4.32</td>
<td>4.385</td>
<td>3.68</td>
<td>3.34</td>
<td>3.51</td>
<td>4.32</td>
<td>4.4</td>
<td>5th Grade Student</td>
</tr>
<tr>
<td>C9</td>
<td>4.82</td>
<td>4.69</td>
<td>4.755</td>
<td>3.84</td>
<td>3.55</td>
<td>3.695</td>
<td>16.13</td>
<td>5.24</td>
<td>5th Grade Student</td>
</tr>
<tr>
<td>C10</td>
<td>4.15</td>
<td>3.76</td>
<td>3.955</td>
<td>3.21</td>
<td>3.06</td>
<td>3.135</td>
<td>4.05</td>
<td>4.68</td>
<td>5th Grade Student</td>
</tr>
<tr>
<td>C11</td>
<td>5.75</td>
<td>4.62</td>
<td>5.185</td>
<td>4.98</td>
<td>5.02</td>
<td>5</td>
<td>16.43</td>
<td>8.01</td>
<td>5th Grade Student</td>
</tr>
<tr>
<td>C12</td>
<td>3.74</td>
<td>4.17</td>
<td>3.955</td>
<td>3.48</td>
<td>3.3</td>
<td>3.39</td>
<td>4.5</td>
<td>4.78</td>
<td>5th Grade Student</td>
</tr>
<tr>
<td>C13</td>
<td>3.46</td>
<td>4.41</td>
<td>3.935</td>
<td>3.89</td>
<td>3.03</td>
<td>3.46</td>
<td>28</td>
<td>4.12</td>
<td>5th Grade Student</td>
</tr>
<tr>
<td>C14</td>
<td>3.6</td>
<td>4.31</td>
<td>3.955</td>
<td>3.03</td>
<td>3.11</td>
<td>3.07</td>
<td>15.7</td>
<td>3.88</td>
<td>5th Grade Student</td>
</tr>
<tr>
<td>C15</td>
<td>3.78</td>
<td>3.55</td>
<td>3.665</td>
<td>3.11</td>
<td>3.2</td>
<td>3.155</td>
<td>11.94</td>
<td>4.29</td>
<td>5th Grade Student</td>
</tr>
<tr>
<td>C16</td>
<td>3.98</td>
<td>4.09</td>
<td>4.035</td>
<td>3.47</td>
<td>3.68</td>
<td>3.575</td>
<td>7.8</td>
<td>4.33</td>
<td>5th Grade Student</td>
</tr>
<tr>
<td>C17</td>
<td>4.92</td>
<td>4.99</td>
<td>4.955</td>
<td>4.75</td>
<td>3.89</td>
<td>4.32</td>
<td>27.83</td>
<td>4.22</td>
<td>5th Grade Student</td>
</tr>
<tr>
<td>C18</td>
<td>4.13</td>
<td>4.14</td>
<td>4.135</td>
<td>4.05</td>
<td>3.53</td>
<td>3.79</td>
<td>4.41</td>
<td>4.55</td>
<td>5th Grade Student</td>
</tr>
<tr>
<td>C19</td>
<td>4.05</td>
<td>4.14</td>
<td>4.095</td>
<td>3.3</td>
<td>3.52</td>
<td>3.41</td>
<td>13.54</td>
<td>4.34</td>
<td>5th Grade Student</td>
</tr>
<tr>
<td>C20</td>
<td>5.01</td>
<td>5.23</td>
<td>5.12</td>
<td>4.81</td>
<td>4.66</td>
<td>4.735</td>
<td>10.37</td>
<td>8.27</td>
<td>5th Grade Student</td>
</tr>
<tr>
<td>C21</td>
<td>3.97</td>
<td>3.9</td>
<td>3.935</td>
<td>3.45</td>
<td>3.41</td>
<td>3.43</td>
<td>14.96</td>
<td>4.51</td>
<td>5th Grade Student</td>
</tr>
<tr>
<td>C22</td>
<td>3.81</td>
<td>3.95</td>
<td>3.88</td>
<td>3.04</td>
<td>3.49</td>
<td>3.265</td>
<td>10.37</td>
<td>6.16</td>
<td>5th Grade Student</td>
</tr>
</tbody>
</table>

| Results | 0.70068 | -6.8455 | -0.5736 |

4.46545  3.76477  11.3109  5.03909  64% failed dizzy test once
41% failed dizzy test twice
45% failed eye test
4.5% failed eye test twice
<table>
<thead>
<tr>
<th>Names</th>
<th>Control 1</th>
<th>Control 2</th>
<th>Avg</th>
<th>Stim 1</th>
<th>Stim 2</th>
<th>Avg</th>
<th>Dizzy</th>
<th>Eye</th>
</tr>
</thead>
<tbody>
<tr>
<td>A1</td>
<td>8.06</td>
<td>5.62</td>
<td>6.84</td>
<td>4.66</td>
<td>4.55</td>
<td>4.605</td>
<td>12.31</td>
<td>6.52</td>
</tr>
<tr>
<td>A2</td>
<td>5.02</td>
<td>4.49</td>
<td>4.755</td>
<td>3.95</td>
<td>3.64</td>
<td>3.795</td>
<td>6.68</td>
<td>5.84</td>
</tr>
<tr>
<td>A3</td>
<td>3.41</td>
<td>3.12</td>
<td>3.265</td>
<td>2.65</td>
<td>2.61</td>
<td>2.63</td>
<td>4.91</td>
<td>3.45</td>
</tr>
<tr>
<td>A4</td>
<td>4.34</td>
<td>4.33</td>
<td>4.335</td>
<td>3.27</td>
<td>3.51</td>
<td>3.39</td>
<td>26.11</td>
<td>4.89</td>
</tr>
<tr>
<td>A5</td>
<td>3.16</td>
<td>3.95</td>
<td>3.555</td>
<td>3.11</td>
<td>2.52</td>
<td>2.815</td>
<td>12.59</td>
<td>5.29</td>
</tr>
<tr>
<td>A6</td>
<td>5.74</td>
<td>4.88</td>
<td>5.31</td>
<td>3.94</td>
<td>4.13</td>
<td>4.035</td>
<td>10.45</td>
<td>8.55</td>
</tr>
<tr>
<td>A7</td>
<td>5.86</td>
<td>5.28</td>
<td>5.57</td>
<td>4.59</td>
<td>4.07</td>
<td>4.33</td>
<td>8.66</td>
<td>8.09</td>
</tr>
<tr>
<td>A8</td>
<td>3.17</td>
<td>2.85</td>
<td>3.01</td>
<td>2.57</td>
<td>2.64</td>
<td>2.605</td>
<td>10.02</td>
<td>3.87</td>
</tr>
<tr>
<td>A9</td>
<td>4.36</td>
<td>3.93</td>
<td>4.145</td>
<td>3.78</td>
<td>3.34</td>
<td>3.56</td>
<td>7.1</td>
<td>7.16</td>
</tr>
<tr>
<td>A10</td>
<td>4.43</td>
<td>3.5</td>
<td>3.965</td>
<td>3.14</td>
<td>3.24</td>
<td>3.19</td>
<td>4.77</td>
<td>5.77</td>
</tr>
<tr>
<td>A11</td>
<td>3.86</td>
<td>4.28</td>
<td>4.07</td>
<td>3.38</td>
<td>3.16</td>
<td>3.27</td>
<td>6.56</td>
<td>8</td>
</tr>
<tr>
<td>A12</td>
<td>3.86</td>
<td>3.43</td>
<td>3.645</td>
<td>3.11</td>
<td>3.06</td>
<td>3.085</td>
<td>19.06</td>
<td>6.94</td>
</tr>
<tr>
<td>A13</td>
<td>3.63</td>
<td>3.66</td>
<td>3.645</td>
<td>3.41</td>
<td>3.12</td>
<td>3.265</td>
<td>15.68</td>
<td>5.43</td>
</tr>
<tr>
<td>A14</td>
<td>3.56</td>
<td>2.99</td>
<td>3.275</td>
<td>2.54</td>
<td>2.45</td>
<td>2.495</td>
<td></td>
<td></td>
</tr>
<tr>
<td>A15</td>
<td>4.1</td>
<td>3.92</td>
<td>4.01</td>
<td>3.25</td>
<td>3.05</td>
<td>3.15</td>
<td>3.76</td>
<td>3.28</td>
</tr>
<tr>
<td>A16</td>
<td>6.29</td>
<td>5.91</td>
<td>6.1</td>
<td>3.62</td>
<td>3.13</td>
<td>3.375</td>
<td>5.54</td>
<td>4.03</td>
</tr>
<tr>
<td>A17</td>
<td>3.65</td>
<td>3.65</td>
<td>3.65</td>
<td>3.46</td>
<td>3.52</td>
<td>3.49</td>
<td>4.4</td>
<td>4.8</td>
</tr>
<tr>
<td>A18</td>
<td>4.3</td>
<td>3.32</td>
<td>3.81</td>
<td>3.31</td>
<td>2.88</td>
<td>3.095</td>
<td>3.63</td>
<td>6.24</td>
</tr>
<tr>
<td>A19</td>
<td>8.05</td>
<td>6.56</td>
<td>7.305</td>
<td>5.55</td>
<td>5.02</td>
<td>5.285</td>
<td>10.72</td>
<td>9.01</td>
</tr>
<tr>
<td>A20</td>
<td>4.66</td>
<td>4.16</td>
<td>4.41</td>
<td>4.17</td>
<td>3.71</td>
<td>3.94</td>
<td>9.07</td>
<td>7.38</td>
</tr>
</tbody>
</table>

4.4335 3.47025 9.58 6.02842 65% failed dizzy test once
10% failed dizzy test twice
25% failed eye test once

Results 0.96325 -5.1465 1.5949
Data Analysis

While reviewing the data compiled during the experiments a few numbers really stood out. The average time to cross the forty foot long balance beam was 4.4 seconds. This time stayed the same between the adults and the children. Essentially, the balance beam leveled the playing field and made this experiment about a single group of 42 volunteers instead of a group of adult volunteers and a group of child volunteers. The other piece of data that also supports this analogy is the fact that on average 64.5% of the volunteers failed the dizzy test. Again, this number remained consistent for the adults and children.

The dizzy test and the eye test data supports the pre-experiment hypothesis that stimulation of these components would negatively affect balance and times would increase. The times for the dizzy test increased by nearly 7 seconds in the children set and over 5 seconds in the adult set. The times for the eye test also increased but not as drastically. An increase of .5 seconds in the children and an increase of 1.5 seconds in the adults was seen. However, the glasses worn by the adults were more effective at blocking the ear column piece and the nose seats than the child glasses. It was possible, while wearing the child glasses, for the eye to pick up information out of the
sides and from close to the nose. This may have made it easier for the children.

The foot stimulation data suggests that it may be possible to increase balance with physical stimulation of the feet. Each of the 42 volunteers showed a decrease in elapsed time across the beam following brushing of the feet. The children decreased .7 of a second across the beam and the adults decreased .96 of a second across the beam. Certainly, some learning is taking place, but not this drastic. When one consider that each subject completed the beam test twice without stimulation and twice with stimulation and then compare the time differences between each trials, it is obvious that the motor learning increase does not even compare to the differences between the pre-stimulation and post-stimulation times. A statistical t-test analysis was performed on the elapsed times pre and post foot stimulation to determine if the time differences would be considered significant (p value <.05) and the analysis shows that p values for both the adult subjects and children subjects are both well below significant levels (p=.00188 and p=.00365). This certainly suggests that physical stimulation of the foot has a positive effect on the receptors in the foot.
Similar Experiments and Literature Review

Certainly, the idea of foot stimulation is not new. Ruchin (1991) chronicled the struggle of a baseball player that had lost a portion of his vestibular system and made mention of foot stimulation as a method to help with equilibrium. The player was instructed by his neurologist to walk on deep pile carpet in an effort to stimulate other components of balance.

Tanaka, Shirogane, Izumi, Ino and Ifukube (2005) also confirmed the theory of foot stimulation as a method of improving balance. This particular study looked at the improving balance and posture using mechanical vibration. Two separate groups were subjected to a vibrating mat which stimulated the receptor on the bottom of the feet and then tested for body sway which is an indicator of poor standing balance. The conclusion of this study suggests that brief vibratory stimulation may positively affect postural balance.

Zemkova and Hamar (2008) also tested the effect of proprioceptive stimulation on balance. Using similar methods as the above study this study concludes that proprioceptive stimulation facilitates adjustments of dynamic balance and may lead to temporary balance improvements.
Balance training to improve human performance seems too obvious to require elaboration but systematic review by Zech et al. (2010) does exactly that. This group took a total of 20 randomized clinical trials to test postural control, muscular strength, agility, jump performance, sprint performance, muscle reflex, rate of force development, reaction time and electromyography in an effort to determine if balance training can improve or enhance neuromuscular control and functional performance. The study concluded that balance training can be effective for human improvement but the vast differences in training protocol make it hard to impossible to verify which protocol is more effective. Further research is needed to determine a dose-response relationship between balance training and human performance.

Allum, Carpenter, Honegger, Adkin and Bloem (2002) studied the effects of ageing on balance control. A dual axis rotating platform was used in conjunction with electrodes placed on muscles of the body to study how muscles respond to random changes in standing planes. The study suggested that reductions in the balance correcting reflex of the arm, hip and ankle muscles among the elderly studied may be associated with the falling issues among the elderly. Additionally, the stiffening of the trunk among the elderly, often perceived as beneficial, may also aggravate the loss of balance.
Balance Deficiency Outlook and Ramifications

Balance is crucial for living and performing the activities of daily living. Deficiencies in any of the components of balance would lead to deficiencies in life. This becomes more critical as a person ages. As the body ages, the balance correction reflex slows down which can lead to imbalance and can further regress into loss of balance and falling (Allum et al, 2002). Falling among the elderly is only now being seen as a serious problem and government agencies at the Federal and State level are beginning the process of addressing the issue. However, these early falling protocols are addressing environmental issues like non-slip shoes and throw rugs and safety devices like grab bars and fall monitors and fail to address the balance deficiency that is leading to the fall. Certainly it pays to be safe and proactive when addressing falling issues, but grab bars and fall monitors are addressing the problem after the fall. A safety rail to grab to help prevent a fall or a monitor to call for help after a fall are steps to addressing falls but neither helps in the critical portion of a second when the body is teetering at the edge of its base of support where a minute, subtle correction would have rendered grab bars and monitors unnecessary.

Research, at that critical portion of a second, is needed. Falling is projected to become a 50 billion problem by the year 2020 and steps are
needed to offset this expense (Centers for Disease Control and Prevention, 2012). To spend billions of dollars in research now to find and correct deficiencies in balance to save tens of billions of dollars in the future is actually showing fiscal responsibility. Even if research and development only lead to a minimal balance improvement it could mean the savings of billions of dollars in medical expenses. Being proactive in finding and researching these deficiencies would reduce the reactive protocol methods and subsequent costs.

When men and women reach a certain age, different exams and tests are recommended to check for signs and symptoms of different afflictions. Studies have shown that these afflictions show up at a certain age among men and women and that performing these exams and tests can catch the afflictions in its early stages and treatment and correction can be extremely successful and beneficial. Using this as an example of successful proactive behavior, would it not be beneficial to recommend periodical balance testing to find and possibly correct balance deficiencies before those deficiencies lead to falling and the consequences related to falling.
Future Experiments

Researchers are very much like 6-year-old children. The question “why?” is asked over and over. During the course of the experiment the question of “why?” arose time and time again. So much more on this subject can be explored and so many more questions of “why?” can be asked.

An obvious experiment would involve stimulating the feet of subjects after they have been put through the dizzy or the eye test. It appears that stimulating the feet can cause a positive effect on balance while stimulating the eye and the ear both cause a negative effect on balance. What would the results be after performing both stimulations on groups of subjects. Adding this test and comparing the elapsed times to the control set along with the elapsed times of the ear and eye test by themselves would really test the effectiveness of stimulating the feet.

Another possible experiment would involve experimenting on elderly subjects who are experiencing balance problems. Would further stimulation of a component of balance that is already showing deficiencies cause a drastic effect on balance or would the other components compensate somehow. The subjects for the current experiment were all very healthy and experiencing no balance problems at all. To test subjects who are already
experiencing balance deficiencies would really test the effectiveness of the foot stimulation test.

An experiment involving stimulation of both the eye and the ear at the same time is also a thought. Would the elapsed times after stimulating two components of balance be twice as slow as stimulating only one or would the body figure out a way to compensate?

This experiment was rudimentary and did not involve any high tech equipment at all. Budget and time restraints led to a quicker and rougher experiment than would have been desired. The elapsed times of this experiment were all taken with a stop watch and human error is clearly a factor. Simply redoing this experiment in a lab environment with electronic timing devices would allow for cleaner, more error free data.

Physical stimulation of the feet appears to have some effect on balance. An experiment involving electrical stimulation would be another step in determining the effectiveness of foot stimulation on human balance.

A more in-depth experiment involving strength conditioning among the elderly is also an experimental thought. As the body ages, muscle mass is lost naturally. This natural muscle loss often leads to the bodies inability to naturally correct itself, which may leads to balance issues. As creatine supplements have been shown to help with muscle mass, it may be possible
for the elderly to see an increase in muscle mass from taking said supplements. An experiment involving balance testing after creatine supplementation would certainly verify if muscle loss can be linked to balance deficiencies.

**Conclusion**

Balance is such an everyday part of life that its importance is often overlooked. Certainly, the youth perceive balance as being something that is just “there.” Perhaps if we all had the ability to look forward in life and preview our last decade of life we may come to see balance for being as precarious as it is. The three components of balance; the vestibular component, the visual component and the receptor component must all be working together and at a high level to maximize our balance potential. A deficiency in any one of the components can cause a massive disruption. Whether the disruption is the actual loss of balance or another condition caused by mixed messages among the components of balance does not matter. What matters is that the massive disruption can often lead to a miserable existence. There are many examples of balance exercises designed to improve balance many of which are very effective. For this paper, the more subtle approach of receptor stimulation was experimented. The results of the experiment certainly suggest that receptor stimulation can
have a positive effect on balance and, subsequently, human performance. Several previous studies also support this theory. Certainly, much more work is needed before any such bold statement can be made but the data clearly verifies and legitimizes the need for additional research on this exact topic. Due to the troubling balance outlook among the aging generation in the world today the need for balance research combined with current and flexible falling protocols are reaching critical levels. Any research work at all made in an effort to relieve these critical levels should be considered and welcomed.


Tantorski, E, Functional Neuroanatomy, Unit 4-Receptors, Retrieved from http://faculty.quinnipiac.edu/health/tantorski/Unit4/unit4
