The Balance Trak 500™ -- Normative Data

Objective: Computerized Dynamic Posturography (CDP) is commonly utilized to determine the effects of different sensory conditions on balance. This study utilizes the Balance Trak 500™, a newly designed CDP system, to establish normative data and examine the effects of aging on the vestibular system.

Methods: Over 300 individuals with no vestibular deficits were examined using the Balance Trak 500™. Each individual performed four sensory organization tests and a Limits of Stability (LOS) test. The sensory organization tests consisted of normal and perturbed stability, with and without visual cues. The LOS test analyzed each individual's ability to utilize the ankle strategy. The results from the tests were then compared across ages and sexes using ANOVA.

Results: A minimum of 10 individuals from each decade and gender were studied. Of the sensory organization tests, statistically significant differences (p < 0.01) were noted on both perturbed stability subtests as well as the normal stability eyes closed condition. Specifically, a greater amount of anterior-posterior and lateral sway are noted in the older decades. As a result, stability scores decline with aging. The most significant differences are noted in the LOS subtest where older individuals consistently scored lower. No statistically significant differences were noted on any of the test results with respect to gender.

Conclusions: Balance, like many other functions, undergoes a degenerative process with aging. Decreased postural stability with aging is related to a decline in all three systems: visual, vestibular and ankle proprioception. This aging related process is often exacerbated by concomitant diseases commonly seen in the elderly.

Clinical Significance: Our results demonstrate a natural decline in balance with aging. To effectively prevent falls, a universal screening program should be considered for all individuals starting in the mid-50's. CDP may be used in the screening and diagnosis of individuals with vestibular and balance deficits and in identifying specific sensory conditions which increase a patient's risk for falling. The Balance Trak 500™, unlike its predecessors, uses a piece of foam rather than a tilting platform. Thus it effectively assesses balance in both the anterior-posterior and lateral planes. Individualized physical and vestibular therapy programs can then be developed to prevent falls in those individuals at greatest risk.
Introduction

Each year, over 200,000 Americans sustain a hip fracture. A majority of these are subsequent to a fall. (Tideiksaar) Whether a fall results in a hip fracture or simply a minor laceration or contusion, the social and economic impact can be quite devastating for a patient as well as family members. The pathogenesis of balance dysfunction and falls is complex and multifactorial.

Balance is maintained by the interaction of vestibular, visual and proprioceptive inputs. Disease in any of these systems often leads to dysequilibrium. Although many falls and balance problems can be attributed to a disease process, a large number of otherwise healthy elderly individuals also complain of imbalance and appear susceptible to balance dysfunction. This suggests that the natural process of aging and its effect on each of these sensory systems may play a role in the increased incidence of balance disorders and falls in the elderly population. Balance dysfunction may be further exacerbated by age-related deterioration of central reflex mechanisms and increase in postural response latencies.

The vestibular system, like other systems in the body, is susceptible to the effects of aging. Studies have shown that older individuals are more likely to report a subjective decline in balance than younger individuals. (Gerson), (Sixt) In fact, unsteadiness is the most common postural disturbance, reported by 72% of women and 73% of men over the age of 75. (Sixt) Furthermore, degenerative changes in vestibular nerve cells have been noted with aging and appear to accelerate around age 70. (Rosenhall, 1973) Deterioration in the vestibular system is often implicated in the pathogenesis of falls.

The consequences of a fall range from minor bruises and lacerations to the more serious hip fractures and displacement from the home to a skilled nursing facility. With an increasingly older population, falls prevention becomes not only an important social issue, but also a significant economic factor. Without proper preventative measures, the magnitude of this problem will continue to increase. Thus, early detection of individuals with imbalance and subsequent implementation of proper prevention measures are essential to the prevention of falls.

Diagnosing balance dysfunction is especially important as exercise training has been shown to improve balance in the elderly. (Ledin) In addition, exercise increases bone density in postmenopausal women, delaying or preventing the effects of osteoporosis and therefore, decreasing the likelihood of a fracture, even in the presence of a fall. (Chow)

The use of computerized dynamic posturography (CDP) is one method of detecting postural disturbances. Posturography assesses an individual's ability to maintain balance despite distorted or absent sensory inputs. The relative
contribution of each sensory system is assessed and deficiencies are identified. Studies have shown that posturography scores decline with aging. (Wolfson, 1992) (Peterka, 1990 -- both MCT and SOT) Most prior studies have utilized the Equitest® by NeuroCom, Inc. Our study utilizes a recently developed posturography, the BalanceTrak 500™ by the Vestibular Technologies, Inc.

The BalanceTrak 500™, unlike its predecessors, utilizes foam rubber rather than a tilting platform to introduce distorted proprioception. The use of foam allows for assessment of postural control in the lateral planes in addition to the anterior-posterior plane. This is especially important as a significant number of spontaneous falls occur laterally. (Masden)

This study was conducted to establish normative data for the BalanceTrak 500™, as well as to examine the effects of the natural aging process on balance. Individuals whose scores deviate from age-related norms may then be channeled into exercise training programs.

Materials and Methods

Study participants were recruited from the St. John's Hospital Volunteers and Rehabilitation Staff, the Southern Illinois University Otolaryngology Clinic Staff, Southern Illinois University -- School of Medicine Residents and Medical Students, Sacred-Heart Griffin High School and other members of the community of Springfield, Illinois. Study participation was limited to those individuals who reported no complaints of dizziness or balance disorders in the past 1 year. In addition, subjects with a history of vestibular problems, diabetic peripheral neuropathy, or other significant health problems which may affect their balance were also eliminated.

Following a brief history and physical, each subject was asked to sign an informed consent. He/she was then placed in a safety harness and CDP was performed according to the standard Balance Trak 500™ protocol. (BT500 Handbook) All subjects performed four sensory organization tests: normal and perturbed stability, both with and without visual cues. Each subtest, normal stability - eyes open (NSEO), normal stability - eyes closed (NSEC), perturbed stability - eyes open (PSEO) and perturbed stability - eyes closed (PSEC), was performed for 30 seconds. For each surface, participants performed the test first with their eyes open and then with their eyes closed. An altered visual surround was not used as it is not a part of the standard Balance Trak 500™ test paradigm. In addition to the four sensory organization tests (SOT), all subjects completed a limits of stability test (LOS).

The normal stability subtests and LOS test were performed on a 20" by 20" platform. A four inch piece of foam rubber was placed upon the platform for the perturbed stability condition. All individuals were asked to align the lateral surface of their feet and the lateral malleolus with the vinyl markings on the piezoelectric platform and the foam as described in the protocol. (BT500 Handbook) The platform, designed to detect an individual's center of foot pressure, is connected to a computer with the Balance Trak 500™ software.
program. A standard stability measure was determined for each subject according to the following formula: \( S_{\text{standard}} = 0.55H\sin6.25^\circ \) where \( H \) is height in inches. Stability scores were calculated as:

\[
\frac{(S_{\text{standard}} - A_{\text{max}}) \cdot S_{\text{standard}}}{S_{\text{standard}}}
\]

where \( A_{\text{max}} \) is the axis of maximum sway in inches as determined by the 95% confidence interval. A stability score is calculated for each of the four sensory organization tests for each subject.

All subjects also performed a limits of stability test. This test measures an individual's ability to use ankle strategy in shifting his/her center of gravity over his/her base of support. Each individual was asked to sway as far as possible from his or her ankles, without allowing his or her feet to come up off the platform. Again, for each test, shifts in the center of foot pressure were sensed by the platform and recorded by the software application. Each subtest outcome (forward, backward, left and right) was reported as a percentage of the standard stability measure given above. In addition, a composite LOS score was calculated as follows:

\[
\frac{(RLOS_{\text{max}} - RNSEO_{\text{max}}) \cdot RLOS_{\text{max}}}{RLOS_{\text{max}}}
\]

where "RNSEO_{\text{max}}" is the distance from the origin of the same point used for the maximum actual stability used evaluation on the Normal Stability - Eyes open ellipse, and RLOS_{\text{max}} is the corresponding distance on the ellipse representing the patient's Limit of Stability." (BT500 handbook) The closer all of these scores are to 100%, the less an individual swayed. Conversely, the more an individual swayed, the lower the stability scores.

Similar to other forms of posturography, the BalanceTrak 500™ software has been designed to evaluate patient sway and utilization of ankle strategy based upon an inverted pendulum model. (Nashner '72 and '76) (McCollum '89 and '96) Thus, stability scores are in part determined by the mechanical properties of a person's body and his/her response to the displacing force of gravity. While the software application asks for a subject's height and the piezoelectric crystal-containing platform take into account the weight of an individual, a subject's distribution of mass is not readily available in the final report. Therefore, we felt that calculation of the basal metabolic index (BMI) was an important consideration in the evaluation of normative data and for the purposes of examining age-related effects. A BMI for each patient using the formula:

\[
\text{BMI} = \frac{\text{weight in lbs}}{(\text{height in inches})^2} \times 705
\]

Finally, subjects were grouped by decade and mean stability scores were compared using ANOVA taking into account an individual's BMI.

Results

A total of 261 subjects ranging in age from 12 to 88 participated in the study. See Table 1 for a breakdown of subjects by age and gender.
A minimum of 10 males and 10 females were tested within each decade. The exception to this was with participants in their ninth decade. Although many individuals over the age of 80 were contacted, most had experienced balance difficulty, lightheadedness or dizziness within the past year or had significant health problems and were therefore, not included. All study participants were free of major health problems and were on no medications which could adversely affect their balance.

Mean stability scores were compared for each decade using ANOVA. Covarying for the BMI was more sensitive than co-varying for height and weight individually and therefore, all tests were co-varied with this index. See Table 2 for mean stability scores on each of the five subtests. The table provides overall mean stability scores as well as means by decade.

<table>
<thead>
<tr>
<th></th>
<th>NSEO</th>
<th>NSEC</th>
<th>PSEO</th>
<th>PSEC</th>
<th>LOS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean</td>
<td>92.3</td>
<td>90.8</td>
<td>85.8</td>
<td>75.7</td>
<td></td>
</tr>
<tr>
<td>0-19 yrs</td>
<td>92.4 ± 0.53</td>
<td>90.4 ± 0.63</td>
<td>88.2 ± 0.74</td>
<td>79.0 ± 1.32</td>
<td>87.8 ± 1.31</td>
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<tr>
<td>20-29 yrs</td>
<td>93.6 ± 0.50</td>
<td>92.2 ± 0.60</td>
<td>89.6 ± 0.70</td>
<td>81.6 ± 1.25</td>
<td>88.4 ± 1.24</td>
</tr>
<tr>
<td>30-39 yrs</td>
<td>92.5 ± 0.56</td>
<td>91.6 ± 0.68</td>
<td>87.6 ± 0.80</td>
<td>78.2 ± 1.46</td>
<td>87.2 ± 1.41</td>
</tr>
<tr>
<td>40-49 yrs</td>
<td>93.4 ± 0.55</td>
<td>91.9 ± 0.66</td>
<td>88.3 ± 0.78</td>
<td>79.5 ± 1.38</td>
<td>88.6 ± 1.37</td>
</tr>
<tr>
<td>50-59 yrs</td>
<td>91.9 ± 0.35</td>
<td>91.0 ± 0.58</td>
<td>86.3 ± 0.68</td>
<td>76.5 ± 1.21</td>
<td>85.0 ± 1.20</td>
</tr>
<tr>
<td>60-69 yrs</td>
<td>91.7 ± 0.35</td>
<td>90.0 ± 0.43</td>
<td>85.4 ± 0.50</td>
<td>75.2 ± 0.89</td>
<td>83.5 ± 0.88</td>
</tr>
<tr>
<td>70-79 yrs</td>
<td>92.0 ± 0.33</td>
<td>90.3 ± 0.40</td>
<td>83.4 ± 0.47</td>
<td>71.3 ± 0.84</td>
<td>82.1 ± 0.83</td>
</tr>
<tr>
<td>80-89 yrs</td>
<td>92.3 ± 0.80</td>
<td>91.1 ± 0.96</td>
<td>77.7 ± 1.13</td>
<td>64.8 ± 2.00</td>
<td>80.9 ± 1.98</td>
</tr>
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</table>

Table 2. Stability Scores -- overall mean scores and mean scores by decade

Stability scores for each of the four sensory organization tests were significantly different for males and females. However this difference was eliminated after accounting for the BMI. On the other hand, a significant age-related decrease in stability scores is noted even after co-varying for BMI (p<0.5) This difference is especially pronounced on the perturbed stability conditions (p<0.05). Linear regression analysis of PSEC data with regards to age reveals a 1.3% decrease in scores per decade (95% CI 1.0%-1.7%). The X-intercept of
the regression or the theoretical PSEC stability score at age zero is 83.07. This number would decrease by .13 with each year.

Across all four SOTs, stability scores were slightly lower for individuals under 20 and for those between the ages of 30 and 39 years. Lower scores for individuals in their thirties were felt to represent incidental fluctuations and may be related to sample selection. On the other hand, the slightly lower scores found in individuals under the age of 20 may be explained at least in part by variability in developing motor and postural control found in younger subjects. This variability is also noted in the Limits of Stability (LOS) subtest, where patients are asked to voluntarily shift their center of gravity over their base of support while maintaining postural control.

The LOS test involves shifting one’s center of gravity over his/her base of support in each of four directions: forward, backward, left and right. Similar to the SOT findings, LOS scores decrease with increasing age even after co-varying for BMI. The variations noted with individuals under 20 and those in their 30s are again evident. Of note, there is a significant difference in LOS stability scores in the anterior and posterior directions with respect to height but, not to weight (p< 0.01). Neither height nor weight significantly influence LOS scores in the lateral planes.

Finally, patients were asked about hand dominance to determine if it had an effect on sway in the lateral directions. Hand dominance data was not available for all individuals. Of the 240 subjects with available data, 219 individuals were right handed and 21 were left handed. Ambidextrous individuals were categorized as right- or left-handed based upon the hand used over 50% of the time. Essentially no difference was noted in an individual’s ability to sway in either of the lateral planes and his/her hand dominance.

Conclusions

Falls and their sequelae are a major health hazard among the elderly. Early diagnosis and implementation of preventive measures are essential to preventing injury. As with the prevention of other disease, such as breast and prostate cancer, a method of screening must be established to identify those at-risk for sustaining a fall. This study in conjunction with a previous study done at this institution indicate that the BalanceTrak 500™ may be useful in the screening of patients with balance disorders and in the development of individually tailored falls preventive programs. (ARO paper) The test which appears to be most sensitive and would be most effective as a quick screen is the PSEC subtest. Previous work revealed that individuals with a history of imbalance had significantly lower scores on the BalanceTrak 500™, especially on the combination of foam and absence of visual cues. Many of those with a history of imbalance had significant pathology including vestibular disease, proprioceptive loss and visual disturbances which accounted for their difficulty with postural control. Disease was often responsible for falls in these individuals. (ARO paper)

Although disease may accelerate loss of postural control, our results suggest that some decline in balance function is in fact, an age-related
phenomenon. Thus, it would appear that screening of all elderly individuals is crucial. While it is not possible to prevent the natural process of aging, it may be possible to slow its progression through exercise training. \textit{(Overstall)} \textit{(Ledin)}

Exercise may increase muscle mass and control as well as add to bone density. Thus, even in the presence of a fall, an individual is less likely to sustain a fracture. Finally, the increased activity level of routine exercise may help with weight reduction. Although our analysis did not reveal weight or BMI to be a significant determinant of balance, postural control may be better maintained when the base of support is relatively larger than the mass it must support.

Finally, although this study examines the effects of aging on balance, one important weakness should be noted. While we co-varied for height and weight, using the BMI, studies have shown that the length of an individual's foot is a critical determinant of the maximum torque which may be exerted about the ankle. \textit{(McCollum, '89)} In this study, foot length is accounted for in stability scores by measurements of center of foot pressure by the platform. However, our analysis relied largely upon height which is indirectly proportional to the foot length. Thus, while it is unlikely to change results significantly, future studies should be conducted co-varying for foot length.
References


