A Comparison of Electronystagmography Results with Posturography Findings from the BalanceTrak 500

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Objective: To determine a correlation between conventional electronystagmography findings with results obtained from BalanceTrak 500 posturography assessment.

Study design: Individuals with a variety of dizziness and balance disorder symptoms were tested with both electronystagmography (ocular motor studies, positional/posturing testing, caloric testing) and computer posturography using the BalanceTrak 500.

Setting: Tertiary referral center.

Patients: Urban/rural midwesterners referred for dizziness and balance dysfunction symptoms.

Intervention: Results of both testing modalities were sent to referring physicians.

Outcome Measures: Electronystagmography and posturography results.

Results: When electronystagmography results were compared with BalanceTrak findings, a majority of patients whose electronystagmography findings indicated central and mixed causes, or peripheral lesions other than benign paroxysmal positional vertigo, had abnormal findings on posturography. Specifically, tests similar to the Balance Master Sensory Organization Tests 4 and 5 and a new test, Limits of Stability, presented the most difficulty for these individuals. Patients with normal electronystagmography findings and those with benign paroxysmal positional vertigo had mixed results on posturography. The results for specific individual electronystagmography tests were compared with those of posturography tests. No correlation was noted among any of the electronystagmography results and posturography findings. Furthermore, no correlation was observed between posturography and the causes of dizziness.

Conclusion: For many patients with dizziness and/or balance dysfunctions, posturography can provide additional information to that obtained with electronystagmography. This is especially apparent in individuals who have these symptoms but have normal or borderline normal electronystagmography findings. Key Words: Balance dysfunction—Electronystagmography—Posturography. Otol Neurotol 23:488–493, 2002.

As the global population ages, falls and their consequences are becoming a greater health concern. Each year, 25 to 35% of healthy community-dwelling adults between 65 and 75 years of age report a significant fall. This rate climbs to 32 to 42% for those over age 75. (1) Deterioration in balance, whether a consequence of disease (2) or a natural process of aging (3–6), is more prevalent among elderly individuals. Individuals maintain balance through a complex interaction of three primary systems: vestibular, visual, and proprioceptive. Additionally, the general health of an individual, including central reflex mechanisms and muscle tone and strength, aid in the prevention of falls. (7)

Dizziness is a common reason for falls. In fact, of all persons over age 65 who fall, 15 to 23% report the cause as dizziness or vertigo. (8) Forty percent of men and 60% of women over age 70 describe having dizziness (8). The term dizziness covers a broad range of symptoms, including vertigo, sensations of unsteadiness and/or imbalance, and orthostasis. These symptoms may be the result of a deficit in the vestibular system or, more commonly, of central or multisensory dysfunction. Determining which systems are implicated requires thorough investigation, often aided by ancillary testing.

In an otolaryngology office, patients with dizziness are commonly assessed with an electronystagmography (ENG) battery that may include spontaneous and gaze nystagmus, oculomotor, rotational, positioning/positional, and caloric testing. Electronystagmography is an extremely valuable diagnostic tool in assessing the anatomic and functional integrity of the central and peripheral vestibular systems.

However, not all falls are the result of a deficit in the vestibular system. Many individuals experience a sensation of unsteadiness or feeling “off-balance” as a result...
of decreasing function in other sensory systems. A common cause of falls is the proprioceptive loss from peripheral neuropathy that occurs in patients with diabetes and in those with alcoholism. Failing vision is another common reason for miscalculating a step.

Whereas ophthalmologic examinations provide objective evidence of visual disturbances, objective assessment of the proprioceptive and somatosensory systems is often not addressed. If examined, proprioceptive and somatosensory testing is usually subjective, using pins (pain), tuning forks (vibration), and hot/cold objects (temperature). At best, these tests provide us with a qualitative description of sensory deficits. They do not provide any information regarding the functional disabilities resulting from such losses. An individual’s functional abilities can be quantified with the use of computerized dynamic posturography (CDP), a more sophisticated version of the Romberg test.

Computerized dynamic posturography, a multisensory assessment of balance, often consists of two main tests: sensory organization tests (SOT) and motor coordination tests (MCT). The SOT battery quantifies an individual’s ability to maintain an upright stance with one or more inaccurate or absent sensory inputs. The MCT battery provides information about an individual's response time to a perturbation. Although it offers insight into an individual’s functional status, CDP is often overlooked when balance is assessed.

Controversy exists as to whether CDP offers any additional information from an ENG or other assessment tools such as the Dizziness Handicap Inventory and whether this information is justified by the cost of such testing. (9) A few authors have shown that CDP does indeed offer additional information and can be extremely valuable in facilitating therapeutic decisions for patients with disequilibrium (10–16). CDP assesses a patient’s functional deficits. It is nonlocalizing with respect to lesions. ENG, on the other hand, can provide useful localizing information. Therefore, both types of tests are necessary for the diagnosis and therapeutic management of balance disorders. Unlike individuals in previous studies, our patients underwent CDP on the BalanceTrak 500, a recently developed CDP that is a quantitative version of the traditional “foam and dome” test (17). Although most studies comparing ENG and posturography have used the NeuroCom Inc. Equitest system, one study has compared foam posturography with ENG, including vestibular ocular reflex (VOR) testing. (15) However, the foam posturography in this test was a qualitative examination.

The BalanceTrak 500 (Vestibular Technologies, Tampa, FL, U.S.A.) has several advantages over its predecessors. First, the foam used for testing is a medium that more accurately simulates conditions that may be encountered in daily life. It simulates thick, plush carpeting; rough, uneven terrain (encountered on hiking trails and in the rough on golf courses); and even certain types of heavily padded shoes. Second, unlike a platform, which tilts only forwards and backwards, the foam also assesses a patient’s ability to maintain balance in the lateral plane. The ability to assess an individual’s response to lateral perturbations is especially important because many falls occur laterally (18). Finally, this test is relatively quick and simple to run in the office setting.

The BalanceTrak 500 is strictly a test of sensory organization. The test battery does not include motor coordination tests. This is not crucial; one author has shown that 71% of CDP abnormalities in patients with balance disorders have decreased scores on one or more SOTs, as opposed to 11% with motor coordination dysfunction. (13)

**MATERIALS AND METHODS**

Patients were recruited from the Southern Illinois University–School of Medicine (SIU-SOM) Otolaryngology, Vestibular, and Balance Disorders and Falls Prevention Clinics. All subjects who had undergone posturography on the BalanceTrak 500 between June 1999 and April 2000 and ENG within 1 year of CDP were included in the study. Although a time span of 1 year was chosen, most subjects completed the study within a few weeks of one another. It was thought that the time period was not sufficiently long enough for subjects to have improved function through vestibular rehabilitation exercises. SIU-SOM is a tertiary referral center. Thus, whereas all the posturography testing was completed at SIU, ENG testing was done at one of several locations. Ninety percent of the ENG testing was completed at SIU-SOM. Three fourths of the remaining 10% were completed at the offices of a clinical faculty member using the same equipment as that at SIU. Only three individuals had ENG testing completed in other locations.

**BalanceTrak 500 testing**

After a brief history and physical examination, each subject was asked to sign an informed consent form approved by the Institutional Review Board. The subject was then placed in a safety harness, and CDP was performed according to the standard BalanceTrak 500 protocol. (19) All patients and control subjects performed four sensory organization tests: normal and perturbed stability, both with and without visual cues. Each subtest—normal stability with eyes open (NSEO), normal stability with eyes closed (NSCE), perturbed stability with eyes open (PSEO), and perturbed stability with eyes closed (PSEC)—was performed for 30 seconds. For each surface, patients performed the test first with eyes open (Fig. 1) and then with eyes closed (Fig. 2). An altered visual surround was not used because it is not a part of the BalanceTrak 500 equipment. In addition to the four sensory organization tests, all subjects completed a Limits of Stability (LOS) test.

The normal stability subtests and LOS test were performed on a 20” x 20” platform. A 4” piece of 3.0 ± 0.03 pounds per cubic foot dense 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 malleoli with the vinyl markings on the platform and the foam as described in the protocol. (19) The platform, designed to detect an individual’s center of foot pressure, was connected to a computer with the BalanceTrak 500 software program. A standard stability measure was determined for each subject according to the following formula: 

\[
S_{\text{standard}} = (A_{\text{max}} - H) / S_{\text{standard}}
\]

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

All subjects also performed an LOS test. This test measures an individual's ability to use ankle strategy in shifting his or her center of gravity over his or her base of support. Each individual was asked to sway as far as possible from the ankles without allowing the 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:

$$\frac{(RLOS_{\text{max}} - \text{RNSEO}_{\text{max}})}{RLOS_{\text{max}}}$$

where $\text{RNSEO}_{\text{max}}$ is the maximum actual stability used on the Normal Stability Eyes Open subtest and $RLOS_{\text{max}}$ is the maximum distance of sway on the LOS subtest. The closer all of these scores were to 100%, the less an individual swayed. Conversely, the more an individual swayed, the lower the stability scores.

**Electronystagmography testing**

Each patient also underwent ENG. The test battery consisted of part or all of the following: gaze and spontaneous nystagmus tests, oculomotor tests (saccade, smooth pursuits, and optokinetic studies), rotational chair testing, positioning and positional testing, and caloric testing. The specific test battery completed was left to the discretion of the ordering physician and was based on symptoms and clinical judgment.

Patients taking medications known to suppress vestibular or central nervous system function, such as antihistamines, anxiolytics, or narcotics, were excluded from the study. All patients were asked to refrain from consuming alcohol or caffeine 48 hours before testing.

Standard electro-oculography methods were used to obtain and record eye movements, which were recorded and analyzed by a Gateway 2000 computer using Micromedical Technologies Ultra Version 4.5 software. The light source was a light-emitting diode digital light bar, and subjects were tested sitting with the head in a fixed position in the dark, 1 meter distant from the light bar.

Gaze-evoked nystagmus was tested by having the subject fixate on a still target for 15 seconds in the center, and 20° in the left, right, up, and down positions. Spontaneous nystagmus was tested by having the subject close the eyes in the dark while mentally fixating on the target.

Smooth pursuit, assessed for gain (the ratio of eye velocity to
**TABLE 1. Comparison of ocular motor and posturography test results**

<table>
<thead>
<tr>
<th>BalanceTrak 500 results</th>
<th>Ocular motor results</th>
<th>Posturography results</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normal (n = 61)</td>
<td>5 (7%)</td>
<td>46 (37%)</td>
</tr>
<tr>
<td>Abnormal (n = 83)</td>
<td>47 (38%)</td>
<td>46 (37%)</td>
</tr>
<tr>
<td>Borderline (n = 10)</td>
<td>5 (4%)</td>
<td>5 (4%)</td>
</tr>
</tbody>
</table>

**TABLE 2. Comparison of vestibulo-ocular reflex and posturography test results**

<table>
<thead>
<tr>
<th>BalanceTrak 500 results</th>
<th>Vestibulo-ocular reflex results</th>
<th>Posturography results</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normal (n = 10)</td>
<td>8 (14%)</td>
<td>46 (37%)</td>
</tr>
<tr>
<td>Abnormal (n = 42)</td>
<td>29 (52%)</td>
<td>46 (37%)</td>
</tr>
<tr>
<td>Borderline (n = 4)</td>
<td>3 (5%)</td>
<td>5 (4%)</td>
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</table>

**TABLE 3. Comparison of positional and positioning test results**

<table>
<thead>
<tr>
<th>BalanceTrak 500 results</th>
<th>Positional and positioning test results</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normal (n = 61)</td>
<td>14 (16%)</td>
</tr>
<tr>
<td>Abnormal (n = 63)</td>
<td>42 (48%)</td>
</tr>
<tr>
<td>Borderline (n = 7)</td>
<td>5 (6%)</td>
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</tbody>
</table>

Results met the criteria for abnormal, 21 for normal, and 10 for borderline.

Twenty-seven individuals (22%) of patients had completely normal results on the four SOTs. In the abnormal group, several subgroups of patients were evident. Only 12 patients had increased sway on the NSEO subtest, compared with 91 patients with abnormal sway on the PSEC test. Forty-three individuals had abnormalities on both of the perturbed surface conditions. Fourteen additional individuals also had difficulty with SOT 2. Six individuals exhibited a visual dependence pattern (abnormal SOT 2 and 4 scores.) Overall, the PSEC test result was the most likely to be abnormal. A patient's age (p < 0.01) and height (p < 0.05) were noted to be significantly related to posturography results. Thus, all the tests comparing BalanceTrak 500 results with ENG components were covaried for these two factors.

Tables 1 through 4 compare the number of patients with normal, abnormal, and borderline posturography results with their corresponding results on other tests. Fifty percent of those with abnormal or borderline posturography results had normal ocular motor test results. Of the 21 patients with normal posturography results, 43% had normal oculomotor results. Analysis of covariance comparing mean results on each of the subtests—saccade accuracy and velocity; pursuit gains at 0.1, 0.2, and 0.4 Hz; and optokinetic gains at 0.05 and 0.1 Hz—all failed to find an association between ocular motor testing and posturography.

The VOR results at 0.02, 0.04, 0.08, 0.16, and 0.32 Hz also failed to show a relationship with posturography. Of the 56 individuals undergoing both tests, only 9% showed abnormalities on both tests. By contrast, 69% of those with abnormal posturography results and 80% of those with normal posturography results had a normal VOR result.

Similarly, no significant relationship was noted between positioning and positional testing and posturogra-
TABLE 4. Comparison of caloric testing and posturography test results

<table>
<thead>
<tr>
<th>BalanceTrak 500 results</th>
<th>Caloric testing results</th>
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<tbody>
<tr>
<td></td>
<td>Normal (n = 55)</td>
<td>Abnormal (n = 27)</td>
</tr>
<tr>
<td>Normal (n = 16)</td>
<td>7 (8%)</td>
<td>9 (11%)</td>
</tr>
<tr>
<td>Abnormal (n = 60)</td>
<td>42 (51%)</td>
<td>18 (22%)</td>
</tr>
<tr>
<td>Borderline (n = 7)</td>
<td>6 (7%)</td>
<td>0</td>
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</table>

Phy. Although 33% of those with abnormal posturography results also had abnormal positional or positioning test results, 22% of those with normal posturography results and 29% of those with borderline posturography results had similar results.

Caloric testing was performed to investigate peripheral vestibular weakness. Although an association was initially noted between LOS scores and abnormal caloric results, further testing failed to uphold this finding. Furthermore, no significant relationship was noted among any of the SOT results and caloric findings. In fact, 70% of those with abnormal posturography results had normal findings on caloric testing. Only 22% of individuals had abnormal findings on both examinations. Thus, posturography using the BalanceTrak 500 did not seem to be directly related to the results of any ENG test.

In addition to comparison of individual tests, the patients’ diagnoses were compared with their posturography results to determine whether CDP was sensitive in detecting particular types of lesions. Based on a combination of history, results of ENG testing, and other available test results, such as magnetic resonance imaging and computed tomography, patients received diagnoses of central lesions (43 patients); peripheral vestibular lesions (28 patients); mixed central and peripheral vestibular lesions (11 patients); noncentral, nonperipheral vestibular lesions (41 patients); and lesions of unknown causes (2 patients). In addition to the main groupings described above, 9 of the peripheral vestibular lesion patients and 1 of the mixed lesion patients had a diagnosis of benign paroxysmal positional vertigo. There were no significant differences among patients in the different diagnosis groups with respect to posturography results (Table 5).

Eighty percent of those with a noncentral, nonperipheral vestibular lesion; 79% of those with a central lesion; 61% of those with a peripheral lesion; and 82% of those with lesions of mixed causes had abnormal posturography results. Of the 94 patients with abnormal BalanceTrak 500 results, 35% had noncentral, nonperipheral lesions, 36% had central abnormalities, 11% had a peripheral dysfunction other than benign paroxysmal positional vertigo, 9% had lesions of mixed causes, and 7% had benign paroxysmal positional vertigo. The results from the BalanceTrak 500 did not aid in the localization of a lesion.

DISCUSSION

Electronystagmography and posturography provide different types of information, both of which assist in the diagnosis and therapeutic management of patients. This has been shown by other studies that have also compared different ENG testing with posturography (10–11,12–16). Information from an ENG can assist with lesion localization. However, for information regarding the functional status of a patient, posturography is more useful. The value of doing both tests is especially evident in individuals who are symptomatic but have normal or borderline ENG findings.

Abnormal posturography results ranged from 61 to 82% of all patients within a particular diagnostic group. Patients with peripheral lesions were more likely to have normal posturography results than those with central, mixed vestibular, or nonvestibular, noncentral lesions. These findings are best explained by suppression of inaccurate vestibular cues, increased reliance on alternative sensory systems (visual and proprioceptive), and central compensation. In fact, one study showed that individuals with a peripheral vestibular insult will begin to show a “rewiring” of sensory inputs as early as 3 to 4 days after lesion and central compensation within 1 to 2 weeks. (11) Thus, the variable results within the peripheral vestibular abnormality group may be a function of the time at which the patient was tested and its proximity to the insult, as well as an individual’s ability to compensate.

Not all balance dysfunction and dizziness has a vestibular cause. As our results show, nonvestibular, noncentral lesions are equally responsible for abnormal balance as central lesions. If these individuals had been tested with only ENG, they would have been labeled normal. However, on the basis of posturography results, they were just as likely to fall as their counterparts with central abnormalities. Physical and occupational therapy interventions are warranted in both groups of patients to assist in preventing falls.

TABLE 5. Comparison of diagnosis with posturography findings

<table>
<thead>
<tr>
<th>BalanceTrak 500 results</th>
<th>Diagnosis</th>
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<tbody>
<tr>
<td></td>
<td>C (n = 43)</td>
</tr>
<tr>
<td>Normal (n = 21)</td>
<td>5</td>
</tr>
<tr>
<td>Abnormal (n = 94)</td>
<td>34</td>
</tr>
<tr>
<td>Borderline (n = 10)</td>
<td>4</td>
</tr>
</tbody>
</table>

C, central; P, peripheral vestibular; N, noncentral, nonperipheral vestibular; M, mixed causes; B, benign paroxysmal positional vertigo.

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Functional assessment and subsequent therapy design may be the two most valuable outcomes of posturography testing. One study has shown that exercise, which improves bone mass, can also increase stability; improvements are noted on standing on a perturbed surface as well as with certain balance tests, including standing on one leg with eyes closed or simultaneously shaking one’s head. (21) Improved strength and stability may prevent falls and their consequences.

The BalanceTrak 500, a recently developed and relatively less expensive form of posturography, can be used in the office setting for quick assessment of a patient’s balance capabilities. The use of foam as the perturbation of stance simulates commonly encountered environmental surfaces and provides a more accurate assessment of an individual’s compensatory abilities. As with other forms of posturography, the information obtained from such testing is not redundant, nor should it be used as a sole testing method even in the face of an “obvious” noncentral, nonvestibular lesion such as peripheral vascular disease. An individual’s unsteadiness may have several causes, and all possible sources of imbalance should be investigated to maximize an individual’s functional capabilities.

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REFERENCES