Predicting Fall Risks in an Elderly Population: Computer Dynamic Posturography Versus Electronystagmography Test Results

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Objectives/Hypothesis: Falls are the leading cause of morbidity and mortality for persons aged 65 years and older, with more than 2 million people falling and sustaining serious injury annually. This study compared computer dynamic posturography (CDP) and electronystagmography (ENG) results as predictors of falls. Study Design: Retrospective. Methods: Thirty-three patients over the age of 65 years who presented to a balance disorders and falls prevention clinic were used for this study (22 women and 11 men, with an average age of 78.0 y and a mean fall rate of 3.5 times). All had experienced at least one fall in the year before visiting the clinic and were tested with both CDP and ENG. The CDP results were divided into subcategories (sensory organization testing and limits of stability); ENG results were divided into four categories (ocular motor, rotational chair, positional, and caloric studies). Results: Test findings were classified as normal or abnormal based on age-matched normative data. Of the patients in the study, 27.3% were normal for one type of testing and abnormal for the other. Twenty-six patients (78.3%) had abnormal results on CDP, and 20 individuals (60.6%) showed ENG abnormalities (42.4% for ocular motor, 28.6% for positional, 13.6% for caloric, and 11.2% for rotational chair studies). The limits of stability category was significant in predicting multiple falls. Conclusion: For this population, CDP was determined to be a more sensitive test for identifying patients who have fallen, with limits of stability testing the most significant part of the CDP battery; for ENG studies, the best falls indicator was the ocular motor battery. Key Words: Falls, elderly, balance, posturography, vestibular testing.

Laryngoscope, 111:1528–1532, 2001

INTRODUCTION

The population of individuals over the age of 65 years in the United States is rapidly increasing and is predicted to rise to 40 million by the year 2010 and 80 million by the year 2050. A recent 25-year study has shown that not only has the number of falls in the elderly population increased but also the incidence of fall-induced injuries and deaths has increased significantly.1 Falls are the most common cause of both death and disability in the U.S. population over the age of 65 years, and fall-related injuries account for health care costs exceeding $20 billion annually.2 It is estimated that more than 2 million people in the United States fall and sustain a serious injury each year, and more than half of all individuals 65 years of age and older annually sustain at least one fall.3 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 the age of 75 years.3 Deterioration in balance function, whether a natural process related to aging or as a result of disease,4–6 occurs much more often in the elderly population than in younger individuals. Although humans maintain balance through a complex interaction of three primary systems, vestibular, visual, and proprioceptive/somatic sensory, the general health of an individual, including central reflex mechanisms, and muscle tone, strength, range of motion, and motor skills aid in the prevention of falls. A decrease in the function of all these sensory and motor systems occurs as a function of the natural aging process.7,8


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Supported by the Vestibular Clinic, Division of Otolaryngology, Department of Surgery, Southern Illinois University School of Medicine, Springfield, Illinois. The posturography equipment was provided by Vestibular Technologies, Inc., Tampa, Florida, as a grant-in-kind (m.a.) for use in the Southern Illinois University School of Medicine Vestibular Clinic.

Editor's Note: This Manuscript was accepted for publication April 22, 2001.

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Dizziness is frequently given as a reason for falls in the elderly population. In fact, of all persons over 65 years of age who fall, 15% to 23% report the cause as an episode of dizziness or vertigo and 40% of men and 60% of women over the age of 70 years complain of dizziness. The term “dizziness” can cover a broad range of symptoms including not only true vertigo but also sensations of unsteadiness, disequilibrium, orthostasis, or presyncope. These symptoms may result from a deficit in the vestibular system, but other causes in the elderly population commonly include central or multisensory dysfunction. In addition, systemic dysfunctions such as hypertension, vascular occlusions, vision and hearing losses, small vessel ischemic disease, arthritis, osteoporosis, and diabetes mellitus frequently contribute to balance problems for elderly patients. Determining which systems are impaired requires a thorough patient history and physical examination and is aided by additional testing.

Electronystagmography (ENG) testing that may include gaze, spontaneous nystagmus, ocular motor, rotational, positional, or caloric test components is the most common assessment modality for individuals presenting with complaints of dizziness or balance loss, or both. Electronystagmography is a valuable diagnostic tool in determining the anatomical integrity and functional ability of the central and peripheral vestibular systems and locating the site of lesion for a vestibular disorder.

However, not all falls are the result of lesions in the vestibular system. Many individuals experience a sensation of disequilibrium or unsteadiness as a result of decreasing function in other sensory systems. A common cause of falls is a proprioceptive/somatosensory loss from peripheral neuropathy seen in diabetics and chronic alcoholics. Motor coordination skills decrease with age, as does correct choice of a primary movement strategy. With aging, ankle and hip strategies, commonly used by younger persons for maintaining upright posture following balance perturbation, are chosen less frequently. Instead, geriatric individuals more frequently choose a step strategy when the center of gravity is displaced outside the base of support. However, these individuals are often not capable of moving the stepping foot quickly enough to support their weight, and a fall results.

Failing vision is another common reason for miscalculating a step. New glasses may alter visual feedback to the point of distraction from objects on the ground, causing a tripping behavior, leading to a fall. Refractive errors can cause disequilibrium, particularly with eye movements. Disruptions of the saccade or pursuit ocular motor systems frequently result in visual conflict disequilibrium, particularly when the patient is in a busy visual environment. This is often referred to as “shopping market syndrome.” Cataracts and other age-related vision disorders may result in “fuzzy” or blurred vision or diplopia. Patients with a bilateral peripheral vestibular disorder frequently complain of oscillopsia, particularly with head and body movements or when walking.

Ophthalmological examinations can provide objective evidence into visual disturbances; however, objective assessment of the proprioceptive and somatosensory systems is often not addressed. If examination is performed, testing is usually subjective, using pins (pain), tuning forks (vibration), and hot and cold objects (temperature). At best, these tests provide 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 computer dynamic posturography (CDP), a more sophisticated version of the Romberg test.

Computer dynamic posturography, a multisensory assessment of balance, is composed of two main tests: sensory organization testing (SOT) and limits of stability (LOS) testing. The SOT battery quantifies an individual’s ability to maintain an upright stance with one or more inaccurate or absent sensory inputs. The LOS testing provides information on the patient’s skills in moving the center of gravity over the base of support while maintaining an upright posture as individuals are asked to sway, using ankle strategies and weight shifts only, forward, backward, to the left, and to the right. Although CDP offers insight into an individual’s functional status, it is often overlooked when assessing balance, particularly in the elderly population.

Controversy exists as to whether CDP offers any additional information from ENG or other assessment tools such as the Dizziness Handicap Inventory (DHI) and whether this information is justified by the cost of such testing. However, CDP has been shown by several authors to offer additional information that can be extremely valuable in making therapeutic and rehabilitative decisions for elderly patients with disequilibrium. Although CDP assesses a patient’s functional deficits, it is generally nonlocalizing with respect to site of lesion. On the other hand, ENG can provide useful, localizing information. Therefore, both types of tests are necessary for the diagnosis and therapeutic management of elderly balance-disordered patients who have fallen or are at risk of falling. Unlike subjects in many previous studies, the patients in this project had CDP using the BalanceTrak 500 (Vestibular Technologies, Inc., Tampa, FL), a recently developed CDP test that is a quantitative version of the traditional Clinical Test of Sensory Integration and Balance (CTSIB) or “foam and dome” test. Although a number of studies comparing ENG and posturography have used the NeuroCom, Inc. (Clackamas, OR) systems, one study has compared foam posturography with ENG, including vestibular ocular reflex testing. However, the foam portion of the posturography testing in this study was not assessed in a quantitative fashion.

The BalanceTrak 500 has several advantages over its predecessors. First, the foam used for testing is a medium that more accurately simulates proprioceptive and somatosensory conditions that may be encountered in daily life. It simulates thick, plush carpeting; deep grass; gravel walkways; and even certain types of heavily padded shoes. Second, unlike a platform that perturbs only in the anterior-posterior plane, the thick, compliant foam also assesses a patient’s ability to maintain balance in the lateral plane, allowing for a full 360 degrees of perturbation. This is a particular advantage because many falls occur laterally. Patients are buckled into a harness that attaches to a large metal framework to prevent falls during testing. Third, this test is relatively quick and simple.
to administer in the office setting and can be successfully performed on most elderly balance-disordered patients. The BalanceTrak 500 is strictly a test of sensory organization and limits of stability. The test battery does not include motor coordination tests. This is not crucial because it has been shown that 71% of balance-disordered patients who demonstrate CDP abnormalities have decreased scores on one or more of the SOT tasks, as opposed to 11% with motor coordination dysfunction.12

MATERIALS AND METHODS

Patients were recruited from the Southern Illinois University School of Medicine (SIU-SOM)/St. John’s Hospital Balance Disorders and Falls Prevention Clinic. All subjects who had been seen in the clinic and who had undergone posturography on the BalanceTrak 500 and ENG testing with the Micromedical Technologies, Inc. (version 6.0; Chatham, IL) electro-oculographic and infrared videographic ENG system between July 1999 and June 2000 were used for this study. Additional selection criteria required patients to be at least 65 years old and to have reported at least one significant fall in the 12 months before visiting the clinic. Thirty-three patients presenting in this 1-year time period met all these criteria: 11 male and 22 female patients with a mean fall rate of 3.6 times per person.

Patients taking medications known to suppress vestibular or central nervous system function (i.e., antihistamines, anxiolytics, narcotics, some antidepressants) were excluded from the study. All patients were asked to refrain from use of alcohol or caffeine for 48 hours before testing.

Southern Illinois University School of Medicine is a tertiary referral center. All of the CDP and ENG testing was completed at the clinic site. At the clinic, full battery ENG testing consists of gaze evoked and spontaneous nystagmus testing, ocular motor (pursuit, saccade, and optokinetic) studies, rotational chair testing, and binaural, binocular caloric tests. However, not all individuals in this study received the full battery, based on orders from referring physicians or the otolaryngologist who saw them at the clinic.

BalanceTrak 500 Testing

Following a brief history and physical examination, each patient was asked to sign an informed consent form. He or she was asked to remove his or her shoes and was then buckled into a safety harness, and CDP was performed according to the standard Balance Trak 600 protocol.17 All patients and control subjects performed four sensory organization tests: normal and perturbed stability, both with and without visual cues. Each test included normal stability—eyes open (NS/EO), normal stability—eyes closed (NS/EC), perturbed stability—eyes open (PS/EO), and perturbed stability—eyes closed (PS/EC), performed for 30 seconds. For each surface, patients performed the test, first, with their eyes open and, second, with their eyes closed. An altered visual surround was not used because it is not part of the BalanceTrak 500 test paradigm. In addition to the four SOT tasks, all patients completed LOS testing.

The normal stability subtests and LOS testing were performed on a 20- × 20-inch platform. A 4-inch-thick sheet of foam rubber with a protective covering was placed on the platform for the perturbed stability condition. All individuals were asked to align the lateral surface of their feet and the lateral malloucs with the vinyl markings on the platform and the foam as described in the protocol.17 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 patient according to the following formula: \( S_{\text{trasted}} = 0.55H \sin(2\theta) \) where \( H \) is height in inches. Stability scores were calculated as follows: \( S_{\text{standard}} - A_{\text{max}} \times S_{\text{standard}} \) where \( A_{\text{max}} \) is the axis of maximum sway in inches as determined by the 95% confidence interval (CI). A stability score was calculated for each of the four SOT tasks for each patient.17

Each individual also performed LOS testing, which measures a person’s ability to use ankle strategy in shifting his or her center of gravity over his or her base of support. Each patient was asked to sway as far as possible from his or her ankles, without allowing his or her feet to lift up from the platform. Again, for each test, shifts in the center of foot pressure were sensed by the platform and recorded and analyzed by the software application. Each subset outcome (forward, backward, to the left, and to the right) was reported as a percentage of the standard stability measure given earlier. In addition, a composite LOS score was calculated as follows: \( RLOS_{\text{max}} = \frac{\text{RLOS}_{\text{max}}}{\text{RSNSEO}_{\text{max}}} \times \frac{\text{RLOS}_{\text{max}}}{\text{RSNSEO}_{\text{max}}} \) where RSNSEO_{max} is the distance from the origin of the same point used for the maximum actual stability used evaluation on the NS–EO ellipse, and RLOS_{max} is the corresponding distance on the ellipse representing the patient’s LOS.17 The closer all of these scores were to 100%, the less an individual swayed. Conversely, the higher the amount of sway, the lower the stability scores. Normative data had already been determined for all ages of subjects using this test modality.18

Electronystagmography Testing

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

Standard electro-oculography methods were used to obtain and record eye movements, which were recorded and analyzed by a Gateway 2000 computer using Micron Medical Technologies, Inc. Ultra version 4.5 software. Light source was a light-emitting diode digital light bar, and patients were tested sitting in the dark with the head in a fixed position at a distance of 1 m from the light bar. Gaze-evoked nystagmus was tested by having the patient fixate on a still target for 15 seconds in the center, 20° to the left, 20° up, and 20° down. Spontaneous nystagmus was tested by having the individual close his or her eyes in the dark while mentally fixating on the target.

Smooth pursuit measurements of accuracy, latency, and velocity were made by having the individual visually follow a moving light on a screen while holding his or her head steady. Pursuit gain for each patient was measured and calculated by the computer for each of three target frequencies at 30° maximum velocity: 0.1, 0.2, and 0.4 Hz. Saccade results, performed as 30 random jumps, were analyzed for accuracy, latency, and velocity. Optokinetic gains were assessed at a velocity of 40°/s at frequencies of 0.05 and 0.1 Hz.

The vestibular ocular reflex (VOR) was assessed by sinusoidally rotating each patient with head fixed in a chair at a maximum angular velocity of 50°/s. Gain, phase, and symmetry were calculated for each individual at each of the following frequencies: 0.02, 0.04, 0.08, 0.16, and 0.32 Hz.

Positioning and positional testing consisted of Dix Hallpike tests to the left and right, as well as supine head left, right, and center testing. Caloric testing was performed with a closed-loop water irrigation system. Analysis of variance was used to compare the mean results of each of the CDP and ENG subtests (Table I). The two-tailed Fisher’s Exact Test was used to determine the probability of each subtest in predicting falls (Table II). A total of nine separate subtests were analyzed for abnormal results: five from CDP and four from ENG (Table III).

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RESULTS

Thirty-three patients seen at the Southern Illinois University School of Medicine Balance Disorders and Falls Prevention Clinic in a 1-year time span met the criteria for this study and agreed to participate as research subjects. All underwent CDP and at least one portion of ENG testing at the clinic. The average age was 73 years, and the mean number of falls sustained in the 1 year before visiting the clinic was 3.5 overall, ranging from 1 to 20 falls. Although there was no significant difference between the ages of the male and female patients, the female patients seemed to have a significantly higher fall rate. However, this can be explained by the fact that two of the female patients reported 10 and 20 falls, respectively. When these two individuals were removed from analysis, there was no difference in number of falls between the two sexes (Table IV).

Findings on CDP and ENG were classified as normal or abnormal, based on age-matched normative data.\textsuperscript{16,19} Nine (27.3\%) of the 33 patients had normal results for one type of testing while demonstrating abnormal results for the other. When examining the various subtests of each testing modality, 26 patients (78.8\%) had abnormal results on CDP (70.7\% having abnormal results on LOS testing and 70.7\% showing abnormal scores on SOT). Nineteen (57.6\%) of the elderly individuals had abnormal scores for both SOT and LOS testing, whereas only six (18.2\%) had normal results for all of the CDP subtests.

Twenty (60.6\%) of the elderly fallers showed ENG abnormalities (42.4\% for ocular motor studies, 28.6\% for positional/positioning tests, 18.6\% for caloric tests, and 11.2\% for rotational chair testing). Eighteen patients (54.5\%) demonstrated abnormal results for both CDP and ENG studies, whereas only three of the subjects (9.1\%) had normal findings for all subtests performed for both testing modalities (Table III).

Elderly fallers showed abnormal results on the CDP SOT and LOS subtests at an identical rate, which was almost twice the abnormal result rate for the highest ENG subtest, ocular motor studies. This finding shows the various subtests of CDP to be a more sensitive assessment for determining a history of falls in an elderly balance-disordered population than the different subtests of the ENG battery.

When the two-tailed Fisher’s Exact Test was applied to the various CDP and ENG subtests, only for data from patients who experienced multiple falls (20 patients [60.6\%]), the LOS results were the only subtest of either battery to be significant. This indicates that LOS was significant in predicting multiple falls (Table II).

Analysis of variance was used to compare falls as a dependent variable, covarying for factors of gender and age. Neither factor showed significance, although gender approached a P value of .1 (Table I).

DISCUSSION

Electronystagmography and posturography provide different types of information, both of which assist in the diagnosis and therapeutic management of elderly balance-disordered patients at risk of falling.\textsuperscript{10–16} Information from ENG can assist with the localization of a vestibular lesion, as well as providing useful information for a therapist developing a balance therapy program for an elderly individual. However, for information regarding the functional status of a patient, CDP provides additional and, in many cases, more useful data, as is evidenced by the rate of abnormal test results for the patients in the present study when the two modalities are compared. The value of performing both tests is especially evident in individuals who are symptomatic but have normal or borderline ENG findings, yet demonstrate abnormal CDP findings. This study showed only 9.1\% of the patients to have normal findings for both types of testing, whereas the vast majority of patients (90.9\%) demonstrated at least one abnormal finding. However, the percentage of patients with the most abnormal results was seen for the CDP testing (a difference—78.8\% for CDP compared to 60.8\% for ENG).

These findings can be explained by the fact that CDP is a more sensitive assessment for analyzing multisensory (vestibular, visual, and proprioceptive/somatosenory) losses in patients who show a lack of central compensation, which is frequently the case for the elderly, balance-disordered individual at the highest risk of falling.

Not all balance dysfunction and dizziness have a vestibular etiology. Particularly in the elderly population, nonvestibular dysfunctions are equally responsible for abnormal balance. If these individuals had been tested only with ENG, they could have been diagnosed as having normal balance function. However, based on a comparison between the ENG and CDP results, they are almost twice as likely to experience a fall as their counterparts with ENG-demonstrated peripheral and central vestibular abnormalities. Physical

\begin{table}
\centering
\caption{Patient Demographics.}
\begin{tabular}{llll}
\hline
\textbf{Category} & \textbf{No. of Individuals} & \textbf{Mean Age} & \textbf{Mean No. of Falls} \\
\hline
Total group & 33 & 78.0 & 3.5 \\
Males & 11 & 58.8 & 1.8 \\
Females & 22 & 79.0 & 4.2 \\
\hline
\end{tabular}
\end{table}

\begin{table}
\centering
\caption{Abnormal Test Results (in percent of total tested).}
\begin{tabular}{lcccccccc}
\hline
\textbf{Category} & \textbf{CDP} & \textbf{SOT} & \textbf{FS/E0} & \textbf{FS/EC} & \textbf{PS/E0} & \textbf{PS/EC} & \textbf{LOS} & \textbf{ENG} & \textbf{OM} & \textbf{Rot.Ch.} & \textbf{Posit.} & \textbf{Calor.} \\
\hline
Total & 78.8 & 70.7 & 6.1 & 18.2 & 66.7 & 70.7 & 70.7 & 60.0 & 42.4 & 11.1 & 26.6 & 13.5 \\
M & 72.7 & 72.7 & 18.2 & 36.4 & 72.7 & 72.7 & 45.5 & 63.6 & 27.3 & 0.0 & 42.9 & 20.0 \\
F & 81.8 & 68.2 & 0.0 & 9.1 & 63.6 & 60.2 & 81.8 & 59.1 & 50.0 & 14.3 & 21.4 & 11.7 \\
\hline
\end{tabular}
\footnotesize{CDP = computer dynamic posturography; SOT = sensory organization tests; FS/E0 = firm surface/eyes open; FS/EC = firm surface/eyes closed; PS/E0 = perturbed surface/eyes open; PS/EC = perturbed surface/eyes closed; LOS = limits of stability; ENG = electronystagmography; OM = ocular motor battery; Rot.Ch. = rotational chair testing; Posit. = positional and positioning testing; Calor. = bithermal, bilateral caloric irrigation testing.}
\end{table}

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and occupational therapy interventions are warranted in both groups of patients to assist in preventing falls.20

Functional assessment and subsequent customized balance 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 with improvements 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 Also, numerous studies have demonstrated the efficacy of a vestibular and balance rehabilitation program in promoting central compensation, improving gait and balance, and preventing falls.20 Increased strength and stability also aid in the prevention of falls and their frequently drastic consequences for the elderly individual.

CONCLUSION

Posturography, particularly the subtest of LOS testing, provides important information regarding the possible risk of falling for elderly individuals. Computer dynamic posturography, such as the BalanceTrak 500, can be used as a relatively quick and accurate assessment of a patient's overall balance capabilities, and to infer falls risks. 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 diagnosis, such as peripheral vascular disease. Although ENG testing, particularly the ocular motor battery, remains an important assessment for the elderly individual complaining of disequilibrium and loss of balance, additional information can be provided by posturography. A significant number of these aging patients have multisensory deficits, and multiple causes may exist for their loss of balance symptoms. Therefore, all possible sources of data regarding their balance should be used to determine the elderly patient's risk of falling. This aids the physician in maximizing the elderly individual's functional balance capabilities to prevent falls by using interventions such as a customized therapeutic balance rehabilitation program.

Acknowledgments

The authors thank Mary Neill, MA, CCC-A, for her assistance with this project.

BIBLIOGRAPHY