OBJECTIVE QUANTIFICATION
OF BALANCE & MOBILITY
The goal in managing balance and mobility disorders is the minimization of disability and improvement of functional performance. However, patients with similar pathologies frequently present with significant differences in impairments and functional limitations. Because of these differences, patients with similar pathologies respond differently to a given treatment. The most effective strategy to managing these complex patients is an evidence-based multidisciplinary approach that focuses on impairments, functional limitations, and resultant disability, while taking pathological information into account (Figure 1). In fact, clinical outcome studies have demonstrated that management models utilizing impairment reduction treatment strategies customized to each individual patient’s impairments are cost-effective and provide better outcomes than models focusing on pathology alone.\(^5\)\(^8\)

NeuroCom offers a comprehensive library of balance and gaze stability assessment protocols that quantify the impact of impairments on a patient’s ability to perform mobility tasks required for safe and effective function in daily life.

All NeuroCom assessment protocols are consistent with the World Health Organization (International Classification of Function (ICF))\(^2\),\(^3\) and have been validated by extensive scientific and clinical research.\(^9\)
QUANTIFYING IMPAIRMENTS OF BALANCE AND MOBILITY

NeuroCom IMPAIRMENT ASSESSMENTS complement information obtained through the diagnostic examination and provide unique, objective information to accurately isolate and differentiate sensory and motor system impairments underlying a patient’s functional limitations and disabilities. These findings complete the clinical picture to provide a solid foundation for the treatment plan.

Assessments of SENSORY IMPAIRMENTS evaluate the patient’s effective use of visual, vestibular, and somatosensory (support surface) information for balance control during a variety of changing task conditions. Assessments of MOTOR IMPAIRMENTS evaluate the effectiveness of automatic and voluntary motor systems in controlling balance and mobility during a variety of tasks. Tests of DYNAMIC VISION quantify the impact of Vestibulo-Ocular Reflex (VOR) pathology on a patient’s ability to maintain visual acuity and stable gaze during head movement. Tables 1-4 summarize the sensory, automatic motor, voluntary motor, and gaze stability assessments available on NeuroCom systems. Each test is discussed in detail later in this book.

Table 1: Sensory Impairment Assessments

<table>
<thead>
<tr>
<th>Test</th>
<th>Sensory Impairments</th>
<th>Clinical Application</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sensory Organization Test (SOT)</td>
<td>Postural control</td>
<td>All balance and mobility disorders</td>
</tr>
<tr>
<td></td>
<td>Effective use of sensory systems:</td>
<td>Peripheral/central vestibular deficits</td>
</tr>
<tr>
<td></td>
<td>• Vestibular</td>
<td>Post head injury</td>
</tr>
<tr>
<td></td>
<td>• Visual</td>
<td>Fall risk (elderly, mobility disorders)</td>
</tr>
<tr>
<td></td>
<td>• Somatosensory</td>
<td>CNS movement disorders</td>
</tr>
<tr>
<td></td>
<td>Visual-vestibular conflict resolution</td>
<td>Musculoskeletal</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Orthopedic</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Medical-legal</td>
</tr>
<tr>
<td>Head Shake-Sensory Organization Test (HS-SOT)</td>
<td>Coordination of head movement and balance control</td>
<td>Evaluation of higher performance capabilities</td>
</tr>
<tr>
<td></td>
<td>Balance control under dual-task conditions</td>
<td>Compensated peripheral vestibular deficits</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Post BPPV evaluation</td>
</tr>
<tr>
<td>modified Sensory Organization Test (mSOT)</td>
<td>Postural control</td>
<td>Peripheral/central vestibular deficits</td>
</tr>
<tr>
<td></td>
<td>Effective use of sensory systems:</td>
<td>Post head injury</td>
</tr>
<tr>
<td></td>
<td>• Vestibular</td>
<td>Fall risk (elderly, mobility disorders)</td>
</tr>
<tr>
<td></td>
<td>• Visual</td>
<td>CNS movement disorders</td>
</tr>
<tr>
<td></td>
<td>• Somatosensory</td>
<td>Musculoskeletal</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Orthopedic</td>
</tr>
<tr>
<td>modified Clinical Test of Sensory Interaction on Balance (mCTSIB)</td>
<td>Balance control under altered visual and/or surface conditions</td>
<td>Identification of the presence of balance problems</td>
</tr>
<tr>
<td></td>
<td></td>
<td>All balance and mobility disorders</td>
</tr>
</tbody>
</table>

The mCTSIB does not isolate impairments within individual sensory or motor systems.
COMPUTERIZED DYNAMIC POSTUROGRAPHY (CDP)

Computerized Dynamic Posturography (CDP) is defined by the American Academy of Otolaryngology-Head and Neck Surgery (AAO-HNS) as the test protocol comprised of the Sensory Organization Test and motor coordination tests (Motor Control Test and the Adaptation Test).\(^9\) CDP is considered the gold standard in the impairment diagnosis of patients with dizziness/vertigo and disequilibrium of both known and unknown etiologies, as well as in medical case management.\(^10\) It is recognized as a necessary component in the disability evaluation of patients with chronic balance or dizziness disorders\(^11\) and is considered to be medically appropriate in the evaluation or treatment of patients with suspected vestibular disorders.\(^12\)

### Table 2: Automatic Motor Impairment Assessments

<table>
<thead>
<tr>
<th>Test</th>
<th>Automatic Motor Impairments</th>
<th>Clinical Application</th>
</tr>
</thead>
<tbody>
<tr>
<td>Motor Control Test (MCT)</td>
<td>Automatic stabilizing response to external perturbation</td>
<td>CNS movement disorders</td>
</tr>
<tr>
<td></td>
<td>Timing, strength, symmetry of response</td>
<td>Metabolic diseases affecting balance</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Medico-legal</td>
</tr>
<tr>
<td>Postural Evoked Response (PER)</td>
<td>Deficits within pathways mediating automatic stabilizing responses</td>
<td>Metabolic diseases affecting balance</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Peripheral neuropathy</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Degenerative CNS disease</td>
</tr>
<tr>
<td>Balance Strategy Analysis</td>
<td>Selection of appropriate ankle and hip strategy</td>
<td>All balance/mobility disorders</td>
</tr>
<tr>
<td>Adaptation Test (ADT)</td>
<td>Response adaptation to irregular/varying support surface conditions</td>
<td>Fall risk (elderly, mobility disorders)</td>
</tr>
<tr>
<td></td>
<td>Ankle strength/range of motion</td>
<td></td>
</tr>
</tbody>
</table>

### Table 3: Voluntary Motor Impairment Assessments

<table>
<thead>
<tr>
<th>Test</th>
<th>Voluntary Motor Impairments</th>
<th>Clinical Application</th>
</tr>
</thead>
<tbody>
<tr>
<td>Limits of Stability (LOS)</td>
<td>Voluntary control of body movement</td>
<td>Fall risk (elderly, mobility disorders)</td>
</tr>
<tr>
<td></td>
<td>Lower extremity strength, timing, coordination</td>
<td>CNS movement disorders</td>
</tr>
<tr>
<td>Rhythmic Weight Shift (RWS)</td>
<td>Voluntary control of movement and timing initiation</td>
<td>CNS movement disorders</td>
</tr>
<tr>
<td>Weight Bearing Squat (WBS)</td>
<td>Active weight bearing symmetry</td>
<td>Lower extremity injuries</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Weakness</td>
</tr>
</tbody>
</table>

### Table 4: Dynamic Vision Impairment Assessments

<table>
<thead>
<tr>
<th>Test</th>
<th>VOR Impairments</th>
<th>Clinical Application</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dynamic Visual Acuity (DVA) Test</td>
<td>Visual acuity during active head movement</td>
<td>Peripheral/central vestibular deficits</td>
</tr>
<tr>
<td>Gaze Stabilization Test (GST)</td>
<td>Stabilization of gaze for functional activities</td>
<td>Peripheral/central vestibular deficits</td>
</tr>
<tr>
<td></td>
<td>Return to work/high performance activities</td>
<td></td>
</tr>
</tbody>
</table>
NeuroCom **FUNCTIONAL LIMITATION ASSESSMENTS** complement information obtained through the clinical examination and subjective tests by objectively documenting a patient’s ability to safely and efficiently perform balance and mobility activities critical to daily life. These data can be used to better define the goals of a therapy program, monitor progress, and document the outcome of therapy. The assessments are particularly sensitive to limitations in performance resulting from deficits in lower extremity weight distribution, range of motion, and motor control. Table 5 outlines the functional limitation assessments available on NeuroCom systems.

**Table 5: Functional Limitation Assessments**

<table>
<thead>
<tr>
<th>Test</th>
<th>Functional Limitations</th>
<th>Clinical Application</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sit-To-Stand (STS)</td>
<td>Strength, symmetry, and stability of rise</td>
<td>Fall risk (elderly, mobility disorders) CNS movement disorders</td>
</tr>
<tr>
<td>Unilateral Stance (US)</td>
<td>Stability differences between each leg</td>
<td>Lower extremity injuries and weakness</td>
</tr>
<tr>
<td>Walk Across (WA)</td>
<td>Step width/stability, Stride length, Speed</td>
<td>Fall risk (elderly, mobility disorders) CNS movement disorders</td>
</tr>
<tr>
<td>Tandem Walk (TW)</td>
<td>Step width/stability, Speed</td>
<td>Peripheral/central vestibular disorders</td>
</tr>
<tr>
<td>Step/Quick Turn (SQT)</td>
<td>Turn time and stability</td>
<td>Fall risk (elderly, mobility disorders) Peripheral/central vestibular disorders</td>
</tr>
<tr>
<td>Step Up/Over (SUO)</td>
<td>Concentric/eccentric strength and motor control, Symmetry of motor planning/control</td>
<td>Lower extremity injuries, Fall risk (elderly, mobility disorders) CNS movement disorders</td>
</tr>
<tr>
<td>Forward Lunge (FL)</td>
<td>Concentric/eccentric strength and motor control, Symmetry of motor planning/control</td>
<td>Lower extremity injuries</td>
</tr>
</tbody>
</table>

**DOCUMENTATION OF BALANCE AND DYNAMIC VISION IMPAIRMENTS**

Given the complex interaction between pathology(s), body system impairments, function, and disability, NeuroCom test results provide complementary information within a complete medical and rehabilitative examination. The specialized reports generated provide performance information compared to age matched normative performance relative to these special tests and measures of balance and gaze control.

**Comprehensive Reports** provide summary performance data in graphic format, comparing patient performance to age matched normative performance values for each testing measure. The absolute patient performance values for each test trial are provided as **Numeric Data** that can be easily exported for statistical analysis. A variety of **Raw Data** reports provide information relative to Center of Gravity (COG) sway path for each condition/trial, as well as sway and shear forces produced by the patient over the time of each trial.
The **DAILY TRAINING REPORT** summarizes the patient’s training effort, including session duration, specific exercises performed, difficulty levels achieved, and compliance (speed and accuracy). By quantifying the relation between the difficulty level of the exercise and the performance of the patient, compliance scores help ensure an adequate balance between challenge and motor learning.

NeuroCom systems also document the patient’s **TRAINING HISTORY**, which provides the parameters and actual data of the patient’s performance. The View History feature allows the treatment from the previous session to be viewed, updated, and entered for the current session to enhance treatment consistency and efficiency. The treating clinician can quickly view this information and advance the treatment exercises and parameters for the current session accordingly. Treatment planning is easily completed with a few mouse clicks at the beginning of each treatment session, simplifying the procedure for the primary, or substitute, rehabilitation clinician. This improves efficiency and further ensures systematic care between clinicians and treatment sessions. It also allows for more objective evaluation and supervision of practice patterns.

With a single mouse click, the clinician can also blind and save patient data for privacy-protected data sharing for interpretation support, presentation, or education/discussion with colleagues. Blinded files can be viewed with Data Analyzer software supplied with the NeuroCom system.

**IMPLICATIONS TO TREATMENT**

**TRAINING AND REHABILITATION OF BALANCE AND DYNAMIC VISION PROBLEMS**

How does the information from NeuroCom systems affect patient rehabilitation? How are NeuroCom systems used for treatment? And, most importantly, how do NeuroCom systems improve patient outcomes?

Effective training of balance or gaze control to improve mobility is dependent upon having a clear understanding of the causes of the problem. These causes may involve multiple systems, including sensory input and motor output. Information obtained from objective testing differentiates the causes within multiple system impairments and provides the clinician with precise control of what to treat and when. Data-driven decisions give the clinician and the patient confidence that the treatment plan is targeting the impairments most responsible for the balance problem.

Clinicians select appropriate training activities from simple to complex, from seated to standing, to mobility and functional activities—all with precise control over the level of difficulty and the training environment. The power of visual biofeedback enhances patient performance by allowing the patient to detect and correct their own balance errors and the clinician to objectively document progressive improvement. This type of targeted rehabilitation, including setting the right level of difficulty and progressively increasing the challenge, maximizes changes in sensory and motor control to improve balance and gaze.
TARGETED INTERVENTIONS

STEP ONE: CLASSIFICATION BY IMPAIRMENT PROFILE

Patients are classified or grouped not based upon their medical diagnosis, but rather upon the body system impairments identified to be contributing to the balance or gaze control problem. On the basis of this impairment classification, the therapist can narrow the number of intervention choices considerably. This contrasts with traditional rehabilitation models in which there is a broad listing of procedures considered acceptable under the category of balance treatment.

STEP TWO: TARGETED TREATMENT BASED UPON THE IMPAIRMENT PROFILE

The goal of treatment is impairment reduction and to reduce the number of system impairments underlying the balance control problem. Impairment information obtained from NeuroCom assessment protocols serve as triggers for specifically linked therapeutic interventions, and lead to a directory of balance activities appropriate for that problem. Dynamic training focused on key sensory and motor balance system impairments improves not only balance control, but strength, range of motion, gait, and function.
INTRODUCTION
SENSORY IMPAIRMENTS
SENSORY ORGANIZATION TEST (SOT)

The SOT protocol objectively identifies abnormalities in the patient’s use of the three sensory systems that contribute to postural control: somatosensory, visual, and vestibular. During the SOT, inaccurate information delivered to the patient’s eyes, feet, and joints is controlled through calibrated sway referencing of the support surface and/or visual surround. By controlling the usefulness of the sensory information through sway referencing and/or eyes open/closed conditions, it is possible to create sensory conflict situations, which stress the adaptive responses of the central nervous system.

For example, a normal individual will suppress inaccurate inputs and select other, more accurate sensory systems to generate appropriate motor response and postural strategies. Patients with sensory dysfunction may experience a loss of balance when sensory information is disrupted. In short, patients may display either an inability to make effective use of individual sensory systems, or inappropriate adaptive responses, resulting in the use of inaccurate sense(s).

The SOT protocol is comprised of six sensory conditions (Figure 2):

1. EQUILIBRIUM SCORE quantifies the Center of Gravity (COG) sway or postural stability during each of the three trials of the six sensory conditions. Effective use of individual sensory inputs is determined from the overall pattern of scores on the six conditions. The composite equilibrium score (the weighted average of the scores of all conditions) characterizes the patient’s overall level of performance.

As the test results are displayed in real time, the operator can easily identify potential problems with the patient’s performance, or note inconsistencies in the data across trials, and thereby enhance the accuracy of test administration.

SOT COMPREHENSIVE REPORT

Figure 2: Sensory Organization Test
2. **SENSORY ANALYSIS** ratios are used in conjunction with the individual equilibrium scores to identify impairments of individual sensory systems.

<table>
<thead>
<tr>
<th>Ratio</th>
<th>Comparison</th>
<th>Functional Relevance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Somatosensory (SOM)</td>
<td>Condition 2 Condition 1</td>
<td>Patient’s ability to use input from the somatosensory system to maintain balance.</td>
</tr>
<tr>
<td>Visual (VIS)</td>
<td>Condition 4 Condition 1</td>
<td>Patient’s ability to use input from the visual system to maintain balance.</td>
</tr>
<tr>
<td>Vestibular (VEST)</td>
<td>Condition 5 Condition 1</td>
<td>Patient’s ability to use input from the vestibular system to maintain balance.</td>
</tr>
<tr>
<td>Preference (PREF)</td>
<td>Condition 3 + 6 Condition 2 + 5</td>
<td>The degree to which a patient relies on visual information to maintain balance, even when the information is incorrect.</td>
</tr>
</tbody>
</table>

3. **STRATEGY ANALYSIS** quantifies the relative amount of movement about the ankles (ankle strategy) and about the hips (hip strategy) the patient used to maintain balance during each trial. Normal, individuals move primarily about the ankle joints when the surface is stable and shift to hip movements as they become less stable.

4. **COG ALIGNMENT** reflects the patient’s COG position relative to the center of the base of support at the start of each SOT trial. Normal individuals maintain their COG near the center of the support base.

5. **THE SHADED AREA** on each graphic represents performance outside of the normative data range. Green bars indicate performance within the normal range; red bars indicate performance outside the normal range.

**FUNCTIONAL IMPLICATIONS**

Accurate organization of sensory information is critical to maintaining balance within the variety of environments encountered in daily life. An inability to organize sensory information appropriately can result in instability in environments where visual cues are diminished (darkness, lack of contrast/depth cues), the surface is unstable or compliant (sandy beach, gravel driveway, boat deck), or conflicting visual stimuli are present (busy shopping mall, large moving objects such as a nearby bus). Inability to appropriately organize sensory information can lead to or be exacerbated by impairments in COG alignment and/or selection of movement strategies.
Assessment Data Example

A 67 year old female with a history of adult onset diabetes and mild peripheral neuropathy in the lower extremities presents with symptoms of mild, episodic dizziness reported over the previous six months, a mild sense of unsteadiness, and some restriction of daily life activities. Her SOT scores are below normal on sensory conditions 5 and 6, indicating impaired use of vestibular inputs to balance. A Motor Control Test (MCT) is indicated to examine automatic motor reaction times of the lower extremities in relation to her diabetic neuropathy. Given her normal MCT results, rehabilitation focused on the sensory balance impairment, specifically use of vestibular inputs to balance was warranted and led to a successful outcome. As a comparative note, the mCTSIB exam in this case was within normal limits.
HEAD SHAKE-SENSORY ORGANIZATION TEST (HS-SOT)

The HS-SOT protocol is a key enhancement to the standard SOT that is appropriate for patients who perform within the normal range on the standard SOT, yet remain symptomatic. The HS-SOT identifies impairments in the patient’s ability to effectively use vestibular inputs to maintain balance while simultaneously moving the head. Abnormal HS-SOT scores can further demonstrate the movement axes (horizontal, vertical, or roll) that present the maximum challenge to the patient in daily life.

The HS-SOT consists of repeating SOT condition 2 (eyes closed, firm surface) and condition 5 (eyes closed, sway-referenced surface) while the patient wears a head movement monitor and performs a continuous rhythmic head movement about a specified horizontal, vertical, or roll axis. The patient is instructed to maintain the frequency (approximately one turn per second) and amplitude (approximately 30 degrees in each direction for the horizontal axis) of head movement so that the average velocity of the movement is maintained at or above a set minimum. For each condition, the patient is given one unscored practice trial, followed by up to five scored trials. A loss of >30% can be considered significant.

Figure 4: HS-SOT Head Movement Axes

HS-SOT COMPREHENSIVE REPORT

1. EQUILIBRIUM SCORE RATIO The equilibrium score ratio is a comparison of the three-trial average equilibrium score of each head-shake condition to the average score achieved on the comparable condition performed with head fixed. This score is provided only when the SOT and HS-SOT are both performed on the same day.

2. EQUILIBRIUM SCORE displays the individual raw equilibrium scores for the condition 2 and condition 5 trials.

3. (MOVEMENT AXIS) VELOCITY displays the average head movement velocity scores for the selected head movement axis. A horizontal reference line compares the velocity scores to the required minimum velocity. Scores falling below the minimum are highlighted in red, whereas those meeting the criteria are shown in green.
Assessment Data Example

A school-age male presents with concussion from the previous week’s football game. Neuro clinical examination is now normal, but the patient remains symptomatic on SOT conditions 5 and 6 (vestibular system function). In order to provide data to assist the coach in answering the return to play question, a HS-SOT was administered. With the addition of horizontal head movements to conditions 2 and 5 (eyes closed conditions), the patient lost approximately 61% of his postural control (score 0.39). Thus, in high demand activities, such as required in sports performance, the player may lack adequate postural control and be at risk for additional injury or concussion.
FUNCTIONAL IMPLICATIONS

The HS-SOT protocol is more difficult than the standard SOT, and the equilibrium scores of normal patients will be slightly lower on the HS-SOT than on the SOT (<30% difference). Because the HS-SOT provides additional challenges to the sensory organization of balance, it can quantify problems in patients with subtle sensory control problems who perform within normal limits on the standard SOT. The HS-SOT also provides useful objective information relative to the patient’s ability to perform tasks of daily living, many of which involve the ability to actively balance while independently moving the head and eyes.

Head movements challenge the patient by generating a vestibular stimulus in addition to that generated by the patient’s sway. To maintain balance in the absence of alternative visual and somatosensory inputs while moving the head, the brain must differentiate the sway and head-shake stimuli. Degradations in the sensitivity and accuracy of the vestibular receptors, however, can interfere with the process of signal differentiation and reduce stability during head movement. Because the vestibular system is composed of multiple, direction specific sense organs, these degradations may also be axis specific, creating instability only when head movements occur about the involved axis.

In addition to the above effects on vestibular control of balance, head-shaking places an additional task demand on the patient. Some patients with subtle sensory problems successfully perform the standard SOT by exerting conscious effort to augment their impaired automatic reactions. In these cases, the additional task demands of the HS-SOT can abnormally reduce stability by interfering with the patient’s ability to consciously augment balance responses.

Abnormal HS-SOT performance limited to a specific axis is most likely caused by reduced sensitivity and accuracy of receptors acting about that axis. Whereas, HS-SOT problems caused by attentional demands would most likely be independent of the movement axis.

According to recent research, patients with caloric asymmetries of 25% or greater and normal standard SOT results performed abnormally on the HS-SOT in 79% of cases. An even larger 89% of patients with motion provoked symptoms and normal SOT results were abnormal on the HS-SOT.14
MODIFIED CLINICAL TEST OF SENSORY INTERACTION ON BALANCE (mCTSIB)

A modification of the original CTSIB\textsuperscript{15} or “Foam and Dome,” the mCTSIB eliminates the “dome” and adds objective analysis of a patient’s functional balance control to quantify postural sway velocity during four sensory conditions:

1. Eyes open firm surface
2. Eyes closed firm surface
3. Eyes open unstable surface (foam)
4. Eyes closed unstable surface (foam)

The mCTSIB is designed to help the clinician assess the need for further testing in patients with complaints related to balance dysfunction, and to establish objective baselines for treatment planning and outcome measurement. The mCTSIB cannot provide impairment information specific to individual sensory, balance, or motor systems.

mCTSIB COMPREHENSIVE REPORT

1. The COG traces for each trial include numerical values indicating the sway velocity in degrees per second and total trial duration.

2. MEAN COG SWAY VELOCITY for each condition is shown as a bar graph.

3. COMP OR COMPOSITE SWAY is the mean sway velocity averaged over the twelve trials.

4. COG ALIGNMENT reflects the patient’s COG position relative to the center of the base of support at the start of each mCTSIB trial. Normal individuals maintain their COG near the center of the support base.

5. THE SHADED AREA on each graphic represents performance outside of the normative data range. Green bars indicate performance within the normal range; red bars indicate performance outside the normal range. A numerical value is given at the top of each bar.

FUNCTIONAL IMPLICATIONS

The four conditions of the mCTSIB simulate conditions frequently encountered in daily life activities. For most patients with dysequilibrium (with or without established etiology), the mCTSIB will document the presence of a balance problem and provide the information required to support further assessments. The mCTSIB can also be used, to a limited extent, to document progress in a rehabilitation program.
Although the results of the mCTSIB can be used to distinguish normal balance performance versus abnormal balance performance, it cannot be used to discern the specific patterns of dysfunction. The combination of the mCTSIB and LOS forms an objective screening tool for balance problems that can differentiate those patients who will benefit from a course of rehabilitation from those who require further diagnostic testing and more advanced balance rehabilitation.

Assessment Data Example

A 25-year-old male with new onset MS was referred by neurology for balance assessment. Although the patient denies any balance impairment, the mCTSIB shows a beginning balance problem characterized as difficulty on unstable surfaces with vision unavailable. The patient’s awareness of his body position (Center of Gravity) in space is impaired under these conditions. Based on these findings, the patient began participating in a sensory balance program at home and will be followed up annually.
Dynamic Vision Impairments
To maintain visual acuity while the head is moving, an individual’s gaze must be continuously directed towards the object of interest. To maximize visual acuity during head movement, the object of interest must remain centered on the fovea, a small retinal area with the greatest density of visual receptors. The image should move across the fovea at velocities less than 2 degrees per second. In addition, because it takes the brain 20-50 milliseconds to perceive a visual object, these requirements must be maintained for a period of time equal to or longer than this perception time.

When a normal individual moves the head, the vestibulo-ocular reflex (VOR) is the major mechanism by which visual objects are stabilized on the fovea. The VOR stabilizes gaze by reflexively driving the eyes in a direction equal and opposite to the direction of head movement. When the VOR is impaired, visual acuity degrades during head movements, because the direction of gaze relative to objects in the environment changes. Hence, objective measures of dynamic visual acuity can provide useful clinical information about the functional status of the VOR, as well as performance information about an individual’s ability to maintain visual acuity while performing daily life tasks involving head movement.

To effectively use dynamic visual acuity as a measure of VOR function, testing methods must account for the fact that other eye movement systems can, under some conditions, compensate for impaired VOR function. At head movement velocities below approximately 20 degrees per second, the pursuit system can be used to stabilize gaze on fixed visual objects. At higher head movement velocities, predictive and catch-up saccadic movements can be used to stabilize gaze for periods of time long enough for perception to occur. Therefore, to isolate the VOR component of dynamic visual acuity, the test must be designed to rule out the use of compensating pursuit and saccadic systems.

**METHODS COMMON TO inVision™ TESTS OF DYNAMIC VISUAL ACUITY**

To quantify changes in visual acuity during head movement, the patient is seated a prescribed distance from the computer monitor and sequences of the optotype “E” in one of four possible random orientations are briefly presented. When the patient correctly identifies the orientation of the given optotype, the test is progressed and repeated until orientation of the optotype can no longer be reliably determined by the patient. The tests can be performed in each of the three head movement axes, to the left-right as if saying “no”, up-down as if saying “yes”, or rolling the head from side to side.

The patient’s visual acuity thresholds during all testing are determined by using a validated statistical search algorithm, the modified parameter estimation by sequential testing. The first step is to determine the patient’s static visual acuity (SVA). With the head stationary, the patient correctly identifies the orientation of the given optotype, the size is reduced and the process repeated until the orientation of the optotype can no longer be reliably determined. The SVA is the smallest optotype that can be accurately identified.
The next step is to determine the patient’s minimum perception time (MPT) with the Perception Time Test (PTT). When the patient correctly identifies the orientation of the given optotype, the presentation time is reduced and the process repeated until the orientation of the optotype can no longer be reliably determined. The perception time is the shortest presentation time that the optotype can be accurately identified.

Once these baseline measures have been obtained, dynamic vision can be tested using the Gaze Stabilization Test (GST) and the Dynamic Visual Acuity (DVA) test protocols. In the dynamic tests, the patient wears a sensor on the head that continuously measures the position and velocity of head movements and the optotype appears ONLY while the head is moving in the prescribed direction and at or above the minimum velocity. Patients are allowed to practice triggering appearances of the optotype by moving the head in the prescribed direction and minimum velocity. To prevent the patient from predicting the direction and timing of the optotype appearances and thereby compensating with predictive saccades, trials involving the two directions are randomly intermixed, and the presentation of the optotype is randomized within trials.
THE DYNAMIC VISUAL ACUITY (DVA) TEST

The DVA protocol assesses impairments in a patient’s ability to accurately perceive visual objects while actively moving the head on the desired axis at a velocity appropriate to isolate the VOR, 80–120 deg/sec. The duration of optotype presentation is set so that the patient has sufficient time to perceive the optotype during head movement but not enough time to initiate a catch-up saccade. To accomplish this, the minimum display time interval is set at 45 milliseconds or the patient’s MPT, whichever time is greater, with the maximum set to the patient’s minimum interval plus 45 milliseconds.

As the patient correctly or incorrectly identifies the orientation of the optotypes, the size of the optotype is adjusted until the minimum size optotype which can be accurately identified is determined. The actual velocity at which the head was moving during the optotype presentation and the correctness of the patient’s response are recorded for each trial and stored.

DVA COMPREHENSIVE REPORT

1. MINIMUM PERCEPTION TIME The minimum time required to accurately perceive the orientation of the optotypes that are 0.2 logMAR larger than the patient’s SVA is reported.

2. VISUAL ACUITY DIFFERENCE
   Differences between static and dynamic visual acuity are displayed for a given head movement axis. Differences are expressed in logMAR, a unit describing the apparent size of an image based on a ratio of its absolute size to distance from the eye.

3. % LEFT/RIGHT LOSS SYMMETRY
   Differences in Visual Acuity Difference between the two movement directions of a given axis are expressed as a percentage of the sum of the two acuity differences.

4. AVERAGE ACHIEVED VELOCITY
   The head velocity present on the threshold trials is averaged independently for each direction of head movement.
Voluntary Motor Impairments
**LIMITS OF STABILITY (LOS)**

The LOS protocol quantifies impairments in ability to intentionally displace the COG to the patient’s stability limits without losing balance. The patient performs the task while viewing a real-time display of their COG position in relation to targets placed at the center of the base of support and at the stability limits. For each of eight directions, the test measures movement reaction time, movement velocity, movement distance, and movement directional control.

For each of eight trials, the patient, on command, moves the COG cursor as quickly and accurately as possible towards a second target located on the LOS perimeter, set at 100% of the theoretical limits of stability, and then holds a position as close to the target as possible. The patient is allowed up to 8 seconds to complete each trial.

**LOS COMPREHENSIVE REPORT**

1. **THE COG traces for each trial are shown at the top left of the report.**

2. **REACTION TIME (RT)** is the time in seconds between the command to move and the patient’s first movement.

3. **MOVEMENT VELOCITY (MVL)** is the average speed of COG movement in degrees per second.

4. **ENDPOINT EXCURSION (EPE)** is the distance of the first movement toward the designated target, expressed as a percentage of maximum LOS distance. The endpoint is considered to be the point at which the initial movement toward the target ceases.

5. **MAXIMUM EXCURSION (MXE)** is the maximum distance achieved during the trial.

6. **DIRECTIONAL CONTROL (DCL)** is a comparison of the amount of movement in the intended direction towards the target to the amount of extraneous movement away from the target.

7. **THE SHADED AREA** on each graphic represents performance outside of the normative data range. Green bars indicate performance within the normal range; red bars indicate performance outside the normal range. A numerical value is given at the top of each bar.

**FUNCTIONAL IMPLICATIONS**

Ability to voluntarily move the COG to positions within the LOS is fundamental to mobility tasks such as reaching for objects, transitioning from a seated to standing position (or standing to seated), and walking.
Reaction time delays are commonly associated with difficulties in cognitive processing and/or motor diseases. Reduced movement velocities are indicative of high level central nervous system deficits such as Parkinson’s disease and age-related disorders.\textsuperscript{24} Inability to reach targets in single movements, such as reduced endpoint excursions or excessively larger maximum excursions and poor directional control are indicators of motor control abnormalities. Excursions may be restricted by biomechanical limitations. Dizzy and/or unsteady patients and those fearful of falling may artificially restrict their excursions, while the strength of those with lower extremity weakness may be insufficient to attain and/or maintain stable target positions.\textsuperscript{25}

Limitations in the LOS may correlate to risk for fall or instability during weight shifting activities such as leaning forward to take objects from a shelf, leaning back for hair washing in the shower, or opening the refrigerator door. Patients with reduced stability limits in the AP direction tend to take smaller steps during gait, while laterally reduced limits can lead to broad-based gaits.
Assessment Data Example

An 80 year old male presents with a one year history of unsteadiness and falling. He has seen several physicians who advised him that he is “getting old.” All medical tests performed to date are non-contributory. His past medical history is significant for stable diabetes and transient ischemia attack.

His initial LOS testing reveals significantly impaired limits of safe voluntary movement control in all directions, most notably to 35% posterior and 55% anterior. During training, the patient was advanced through a progression of weight-shifting tasks with visual biofeedback. Weight shifts in the problematic directions were then incorporated into functional training activities and environments. The patient achieved 90-100% LOS within the first 30 days of intervention.
RHYTHMIC WEIGHT SHIFT (RWS)

The RWS protocol quantifies the patient’s ability to perform rhythmic movements of their COG from left to right and forward to backward at three distinct paces. During performance of each task, the patient views a real time display of their COG position relative to a target moving at the desired pace and amplitude. For each direction and pace, the RWS measures movement velocity and directional control.

RWS COMPREHENSIVE REPORT

1. The COG traces for each trial are shown at the top of the report.

2. **ON-AXIS VELOCITY** is the average speed in degrees per second of the rhythmic movement along the specified direction. The ideal velocity is shown by the horizontal line on the graph.

3. **DIRECTIONAL CONTROL** is a comparison the amount of movement in the intended direction, toward the end line, to the amount of extraneous movement, away from the end line.

4. **THE SHADED AREA** on each graphic represents performance outside of the normative data range. Green bars indicate performance within the normal range; red bars indicate performance outside the normal range. A numerical value is given at the top of each bar.

FUNCTIONAL IMPLICATIONS

Normal individuals attain the required average velocities by maintaining the rhythm set by the pacing target and by covering the full distance between the specified movement boundaries. At the same time, their movements are straight and well coordinated, with motions in the off-axis direction being a small percentage of the on-axis motion. Patients with motor disorders disrupting normal rhythmic movement control may exhibit slower than normal movement velocities, poor directional control, or a combination of these two problems.²⁶

Functional consequences include an inability to meet the timing demands of the environment, such as crossing the street and stepping onto elevators/escalators. Instability may result when performing activities that require rapid movement speeds, variability in speeds, or changing directions. Rhythmic, reciprocal movement patterns are required in many high level athletic and leisure interests.
Assessment Data Example

A 60 year old female is seen six months following rehabilitation for left hip fracture and total hip replacement. Her mobility continues to be impaired. Test results demonstrate problems with weight acceptance to the fractured side. The front/back results show an inability to accurately control movements when a weight shifting task similar to that required for gait is performed.

Treatment is directed to left and pre-gait weight shifting tasks at variable/progressive limits and speed increments. This task training will then be incorporated into training in related functional activities.
WEIGHT BEARING SQUAT (WBS)

The WBS protocol quantifies the patient’s ability to perform squats with the knees flexed at 30°, 60°, and 90°, while maintaining equal weight on the two legs.

In the erect position, most body weight is borne through the skeletal system, and relatively less stress is placed on the knee and hip joints. Increasing depths of squat place greater stress on the knees and hips, making these positions more sensitive in detecting weight-bearing abnormalities related to lower extremity musculoskeletal injuries.

WBS COMPREHENSIVE REPORT

1. The percentage of body weight borne by each leg is depicted in the bar graph. Numeric values are given for each condition.

2. The **SHADeD AREA** on each graphic represents performance outside of the normative data range. Green bars indicate performance within the normal range; red bars indicate performance outside the normal range.

FUNCTIONAL IMPLICATIONS

Normal individuals maintain body weight within ±7% of equal on the two legs over the full range of squatting positions. Patients with lower extremity orthopedic injuries may exhibit equal weight bearing in the erect position, but will bear a preponderance of weight on the uninvolved side during more stressful squatting positions.

Reduced weight bearing on one leg may reflect sensory (proprioceptive) or strength loss, reduced range of motion, and/or pain. Bending, stooping, and squatting positions substantially increase stress on the ankles and knees, and may identify weight-bearing differences not detectable in a less challenging, fully erect position. Patients with generalized or unilateral weaknesses will demonstrate impaired motor control for sit-to-stand transitions or an inability to safely retrieve objects from the floor. In the athletic population, impairments may result in reduced readiness to move side-to-side or accuracy of weight shift or thrust during squat-to-extend movements.
Assessment Data Example

A 47 year old male is seen six months status post left ACL injury. Although he has normal strength and range of motion as seen on isokinetics, his WBS results show continued symmetry deficits during the highest 90 degree squat conditions. In conjunction with the normal strength and ROM results, this suggests a subtle proprioceptive deficit that should respond favorably to exercise retraining focused on improving left-knee dynamic weight bearing control.
FUNCTIONAL LIMITATIONS OF BALANCE AND MOBILITY
SIT TO STAND (STS)

The STS assessment quantifies the patient’s ability, on command, to quickly rise from a seated to a standing position. The STS quantifies time required to transfer weight from the buttock to the feet (weight transfer time), the strength of the rise (rising index), the symmetry of the rising effort between the left and right legs (weight symmetry), and the COG sway velocity in the standing position.

STS COMPREHENSIVE REPORT

1. **THE COG** trace for each trial is displayed on the left side of the report.

2. **WEIGHT TRANSFER** is the time in seconds required to voluntarily shift COG forward beginning in the seated position and ending with full weight bearing on the feet.

3. **RISING INDEX** is the amount of force exerted by the legs during the rising phase. The force is expressed as a percentage of the patient’s body weight.

4. **COG SWAY VELOCITY** documents control of the COG over the base of support during the rising phase and for 5 seconds thereafter. Sway is expressed in degrees per second.

5. **LEFT/RIGHT WEIGHT SYMMETRY** documents differences in the percentage of body weight borne by each leg during the active rising phase.

6. The **SHADEd AREA** on each graphic represents performance outside of the normative data range. Green bars indicate performance within the normal range; red bars indicate performance outside the normal range. A numerical value is given at the top of each bar.
FUNCTIONAL IMPLICATIONS

Rising from a seated to a standing position is influenced by a number of musculoskeletal, movement control, and balance factors. Accurate control of COG position is critical to controlling the rise movement, as well as to maintaining postural stability. If the COG is not moved sufficiently forward or if the COG is moved too far forward, the patient will either fall back into the chair or fall forward. During the task, lateral stability depends on symmetrical distribution of force between the two legs. The rising maneuver also depends on adequate lower extremity and trunk strength, and range of motion.

The transfer process can be slowed by problems with range, strength, and flexibility in the lower extremity or trunk. Movement or postural control impairments impact speed and COG position and control during the task. Functional consequences include the inability to rise from the seated position during performance of activities, rising from seats of variable heights, or a dependence on upper extremity assistance or the assistance of another person. Safety is a concern if instability occurs during or immediately following the rise, or while descending to sit.
Assessment Data Example

A 38 year old male with right below knee amputation is seen in early prosthetic rehabilitation. In evaluation of sit to stand performance, the patient demonstrates a mild instability during rise to stand (6.7 degrees/second sway velocity) while bearing 8% more weight on the prosthetic side. These results provide the clinician and the patient with objective evidence that the rehabilitation program is proceeding well.
UNILATERAL STANCE (US)

The US assessment quantifies the patient’s ability to maintain postural stability while standing on one leg at a time with the eyes open and closed. The US enhances the observational testing of single leg stance performance by providing an objective measure of patient sway velocity for each of the four task conditions. The length of each trial is ten seconds.

The US is highly sensitive, but not specific because a large number of independent factors can impact performance. A partial list of these factors includes lower extremity strength and weight bearing control, sensory balance control, movement strategies, and prior practice with the task.

US COMPREHENSIVE REPORT

1. The COG traces for each trial are shown at the top of the report.

2. MEAN COG SWAY VELOCITY displays COG stability while the patient stands independently on each leg with eyes open and with eyes closed. The center bar graph displays the percentage difference score with the bar pointing in the direction of the limb with the better performance.

3. The SHADED AREA on each graphic represents performance outside of the normative data range. Green bars indicate performance within the normal range; red bars indicate performance outside the normal range. A numerical value is given at the top of each bar.

FUNCTIONAL IMPLICATIONS

Normal individuals have significantly more sway standing on one foot versus two, and even more sway on one foot with eyes closed. Patients who become unstable may have difficulty using visual or somatosensory information for balance control, and/or may have musculoskeletal problems that make it difficult to compensate. Functional consequences are significant for performance of activities that require single-leg balance, such as donning pants or hosiery, ascending or descending elevations, or navigating narrow support surfaces, such as ladders and scaffolding.
Assessment Data Example
A 26 year old female with a history of congenital strabismus and complaints of increasing balance impairment requested an assessment during a community balance screening event. Her performance, including repeated falls, reveals an inability to perform single limb stance without vision. Further testing may be indicated given the presence of sensory and/or motor problems not consistent with her congenital strabismus.
FUNCTIONAL LIMITATIONS OF BALANCE AND MOBILITY

WALK ACROSS (WA)

The WA assessment quantifies the patient’s steady state gait while walking across the forceplate. The WA enhances observational testing of gait by measuring the average width and length of the patient’s steps on the forceplate, the symmetry of left and right leg step lengths, and the patient’s gait speed across the forceplate. Because of the length of the forceplate, the test may not be appropriate for highly fit individuals whose stride lengths are greater than five feet (152 cm).

WA COMPREHENSIVE REPORT

1. The COG trace for each trial is shown on the left side of the report.

2. **STEP WIDTH** is the lateral distance in centimeters between the left and right feet on successive steps.

3. **STEP LENGTH** is the longitudinal distance in centimeters between successive heel strikes on successive steps.

4. **SPEED** is the velocity in centimeters per second of the forward progression.

5. **STEP LENGTH SYMMETRY** is the comparison of right and left step length, expressed as a percentage of the total stride length (left and right length).

FUNCTIONAL IMPLICATIONS

Gait is a critical element of mobility, which can be affected by a large number of impairments. The WA is therefore a sensitive test of overall functional capabilities, but highly non-specific. Factors influencing gait include cognitive and motor planning abilities, overall conditioning, balance, movement control, strength, and range of motion.

Gait velocity is a useful measure of overall gait ability. Two studies, in which gait velocities of neurologically impaired subjects were compared to their functional levels in daily life activities, found that gait velocities can be used to predict functional limitations in daily life activities. The table on the opposite page lists minimum gait requirements to perform common daily life activities suggested by these studies.

Stride width is an overall measure of balance ability. A study of gait development in young adults/children indicated that stride width (20-25 cm in early walkers decreasing to 10-12 cm in the older children) was an accurate index of postural stability. Together, gait velocity and stride width can be utilized as an objective predictor of rehabilitation potential.
Assessment Data Example
A 38 year old female with a history of autoimmune disorder and two CVAs has undergone two months of rehabilitation. Her discharge WA test reveals symmetrical step length at 25.3 cm, classifying her at the level of supervision for gait. When combined with her walking speed, her gait performance at discharge is adequate for independence on level surfaces and supervision for all non-level surfaces.

<table>
<thead>
<tr>
<th>Daily Life Activity</th>
<th>Velocity</th>
<th>Step Length</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crossing a street</td>
<td>above 120 cm/sec</td>
<td>----</td>
</tr>
<tr>
<td>Normal casual gait</td>
<td>above 98 cm/sec</td>
<td>----</td>
</tr>
<tr>
<td>Unlimited community</td>
<td>above 80 cm/sec</td>
<td>----</td>
</tr>
<tr>
<td>Unlimited household</td>
<td>above 27 cm/sec</td>
<td>----</td>
</tr>
<tr>
<td>Independent on all surfaces</td>
<td>above 65 cm/sec</td>
<td>45 cm</td>
</tr>
<tr>
<td>Independent on level surfaces</td>
<td>above 40 cm/sec</td>
<td>38 cm</td>
</tr>
<tr>
<td>With supervision</td>
<td>above 17 to 24 cm/sec</td>
<td>22 to 32 cm</td>
</tr>
<tr>
<td>With physical assistance</td>
<td>above 14 to 23 cm/sec</td>
<td>20-22 cm</td>
</tr>
</tbody>
</table>
TANDEM WALK (TW)

The TW assessment quantifies the stability and speed of the patient’s gait while placing one foot directly in front of the other. The patient is instructed to walk heel to toe from one end of the forceplate to the other as quickly as possible and then stop. The TW measures the average width of the patient’s steps on the forceplate, the speed of the gait, and the patient’s COG sway velocity following termination of the gait.

TW COMPREHENSIVE REPORT

1. The COG trace for each trial is shown on the left side of the report.

2. **STEP WIDTH** is the lateral distance in centimeters between the left and right feet on successive steps.

3. **SPEED** is the velocity in centimeters per second of the forward progression.

4. **END SWAY** is the velocity in degrees per second of the anterior/posterior component of COG sway for 5 seconds beginning when the patient terminates walking.

5. The **SHADEd AREA** on each graphic represents performance outside of the normative data range. Green bars indicate performance within the normal range; red bars indicate performance outside the normal range. A numerical value is given at the top of each bar.

FUNCTIONAL IMPLICATIONS

Tandem gait is a high demand activity requiring careful control of both COG movement and the successive re-establishment of a stable, narrow base of support. Compared to normal gait, the tandem walk test tends to be more specific to impairments affecting balance.

Patients with COG control problems often compensate by increasing their step width and broadening their base of support to make balancing easier. Slower gait speeds have been shown to correlate with frailty, functional loss, and fall risk in the elderly. Inability to walk quickly may be caused by strength or range of motion impairments, or movement disorders. Self-restriction in speed may be due to sensory loss, fear of falling, or avoidance. Excessive end sway can be a measure of muscular strength and volitional control.
Assessment Data Example

A 25 year old male diagnosed with Multiple Sclerosis presents with mild sensory and movement speed impairment. Despite beginning sensory and motor impairments, his gross motor performance in tandem walk is within normal limits and consistent with his perception of no functional deficits.
STEP/QUICK TURN (SQT)

The SQT assessment quantifies turn performance characteristics. The patient is instructed to take two forward steps on command, and then quickly turn 180° to either the left or right and return to the starting point. The SQT enhances commonly used observational tests for turn stability by measuring separately for each direction of turning, the time required to execute the turn, and the velocity of COG sway during the turn.

SQT COMPREHENSIVE REPORT

1. The COG trace for each trial is shown on the left side of the report.

2. TURN TIME quantifies the number of seconds required for the patient to execute the 180-degree in-place turn. Time begins when forward progression is arrested and ends when forward progression in the opposite direction is initiated.

3. TURN SWAY quantifies the postural stability of the patient during the turn time defined above. Turn sway is expressed as the average COG sway velocity in degrees per second.

4. LEFT/RIGHT WEIGHT DIFFERENCE documents percent differences in the Turn Time and Turn Sway data.

5. The SHADED AREA on each graphic represents performance outside of the normative data range. Green bars indicate performance within the normal range; red bars indicate performance outside the normal range. A numerical value is given at the top of each bar.

FUNCTIONAL IMPLICATIONS

Ability to quickly change direction of travel is a critical component of normal mobility. The task is sensitive to impairments of balance because the patient must maintain stability during the turn while the visual and vestibular inputs are being disturbed by rapid turning of the head and eyes. The functional consequences are an inability to perform activities requiring rapid turns, such as dancing or sports, and increased risk for falls during normal activities of daily living that require turning.

Although stability during turning is a widely used clinical sign of gait and postural deficits, we know of no quantitative descriptions of normal turn performance. Impaired turns, however, have been clinically described as “slow,” “unsteady,” and “irregular in amplitude and timing.” Impaired turns have been reported to be characteristic of some neurological disorders such as cerebellar syndromes and Parkinson’s disease and most high level neurological disorders, for example, “senile” gait, as well as vestibular dysfunction.
Assessment Data Example

A healthy 26 year old female athlete is five years post rehabilitation for Guillan Barre syndrome. Though considered fully recovered, she is discouraged that she is unable to return to sports. Performance on the SQT shows a surprising and significant difficulty with speed of turning, as well as turning stability bilaterally. This raises the question of residual sensory and motor problems from the GBS versus another co-morbidity, and further clinical studies are recommended.
**FUNCTIONAL LIMITATIONS OF BALANCE AND MOBILITY**

**STEP UP/OVER (SUO)**

The SUO assessment quantifies the patient’s ability to control their body weight and postural stability while stepping up and down over a curb. The patient is instructed to step up onto a curb on command with one foot, swing the other foot over the curb while lifting the body through an erect standing position as quickly as possible, and then lower the body weight to land the swing leg as gently as possible. The SUO measures, for each leg, the strength of the rise (lift-up index), the movement time, and the impact of the swing leg landing (impact index).

The SUO is a multi-segmented task critical to negotiating curbs and climbing and descending stairs. The lift-up phase relies primarily on concentric leg strength to elevate the body onto the step. The descent phase in which the body is lowered back onto the floor requires not only eccentric leg strength, but also motor planning so that the swing leg lands on the floor with minimal impact.

**SUO COMPREHENSIVE REPORT**

1. The COG trace for each trial is shown on the left side of the report.

2. **LIFT-UP INDEX** quantifies the maximum lifting (concentric) force exerted by the leading leg and is expressed as a percentage of the patient’s weight.

3. **MOVEMENT TIME** quantifies the number of seconds required to complete the maneuver, beginning with the initial weight shift to the non-stepping leg and ending with the impact of the lagging leg onto the surface.

4. **IMPACT INDEX** quantifies the maximum vertical impact force as the lagging leg lands on the surface, expressed as a percentage of body weight.

5. **LEFT/RIGHT WEIGHT DIFFERENCE** documents percent differences in performance between the left and right legs.

6. The **SHADED AREA** on each graphic represents performance outside of the normative data range. Green bars indicate performance within the normal range; red bars indicate performance outside the normal range. A numerical value is given at the top of each bar.

**FUNCTIONAL IMPLICATIONS**

Climbing stairs and negotiating curbs and other obstacles is a critical element of gait in daily life. For patients with balance and mobility problems, descending stairs can be one of the most challenging demands in their daily activities. Like gait, stair climbing/descending is a complex activity that can be affected by a large number of impairments. Therefore, the SUO is generally a sensitive, but not specific, test of balance and mobility function.

Published evidence supports that the impact index may be a highly specific measure of lower extremity proprioceptive motor control deficits in patients with ACL injuries, even when strength and ROM are within normal limits in the involved knee.\(^{34, 35}\)
Assessment Data Example

A 55 year old woman is seen five years status post MVA with multi-trauma. She is independent in the community with lower extremity pain secondary to multiple fractures and musculoskeletal limitations. An SUO performed on a 4-inch elevation reveals measurable impairment in power production and movement time bilaterally. These findings highlight that the demand of community level function with elevations normally exceeding 6-8 inches in height surpass the patient’s present abilities. The findings direct the clinician to specific impairments and a suitable starting point for rehabilitation efforts.
FORWARD LUNGE (FL)

The FL assessment quantifies the patient’s ability to control body weight while lunging forward with one leg. The patient is instructed to, on command, lunge/step forward onto one leg, then push backward with that leg to the original standing position. The FL measures separately for each leg, the distance of the lunge as well as the profile of the vertical force exerted by the lunging leg (force impulse) during the landing and push off phases of the maneuver.

FL COMPREHENSIVE REPORT

1. The COG trace for each trial is shown on the left side of the report.

2. Above the COG trace, **VERTICAL FORCE** is illustrated as a percentage of body weight for duration of the contact time.

3. **DISTANCE** is the lunge length expressed as a percentage of the patient’s height, as characterized by forward movement of the COG.

4. **IMPACT INDEX** is the maximum vertical force exerted by the lunging leg onto the surface during the landing, expressed as a percentage of the patient’s body weight.

5. **CONTACT TIME** is the duration in seconds of surface contact with the lunging leg in the forward direction.

6. **FORCE IMPULSE** is a measure of the total work performed by the lunging leg during the landing and thrust phases of the movement. Force impulse is expressed as a percentage of body weight (force) multiplied by the time the force is exerted in seconds.

7. **LEFT/RIGHT SYMMETRY** documents percent differences in performance between the left and right legs.

8. The **SHADED AREA** on each graphic represents performance outside of the normative data range. Green bars indicate performance within the normal range; red bars indicate performance outside the normal range. A numerical value is given at the top of each bar.

FUNCTIONAL IMPLICATIONS

Normal lunge distances approach the body height and impact indices are typically small. Patients able to perform more useful work with the knee joint muscles achieve higher force scores. Satisfactory performance on this challenging test requires strength, range of motion, balance, coordination, and control.

Functional consequences are in the ability to participate in sports or occupational activities requiring rapid and significant limb loading and unloading. There is also a risk of injury in circumstances where rapid loading occurs involuntarily. When stepping, the ability to achieve an adequate stepping strategy and maintain postural control can be a measure of balance and safety in mobility impaired patients.
Assessment Data Example

A 28 year old male amateur soccer player has completed a course of rehabilitation following right knee injury and the clinical question is one of safe return to play. Test results reveal a 6-7% deficit in performance of a right FL, with decreased distance, force production, and work. The therapist repeats the test at the completion of the session to examine the effects of muscular fatigue on his performance, finding a 20% right FL deficit, and concludes that his risk of re-injury continues to be high.
THE VALUE OF OBJECTIVE INFORMATION
INFORMATION APPLICATIONS

Applications for objective information in clinical management are as diverse as the team and the services they provide. In an evidence-based practice, clinicians use information to:

1. Determine and justify the levels and types of services appropriate for individual patients.
2. Formulate individualized treatment plans.
3. Monitor and adjust plans as necessary.

In addition, information is also used during rehabilitation exercises to:

5. Focus patients on appropriate tasks.
6. Ensure that the tasks are performed correctly.
7. Maintain patient motivation.

The types of information and the complexity and format of presentation vary with the application. NeuroCom assessment and rehabilitation tools provide clear documentation of objective evidence to support the above applications as follows:

**COMPREHENSIVE REPORTS** facilitate treatment planning with objective graphic and numerical documentation of specific sensory and motor impairments.

**EVALUATION NOTES** provide written summaries of the comprehensive reports. These summaries assist in communicating treatment plans to referring physicians and third party payers.

**PROGRESS REPORTS** document outcomes by graphically charting changes in key impairment and functional limitation measures over the course of treatment. These reports provide supportive data to justify payment or continuation of rehabilitative services.

**TRAINING REPORTS** provide treating clinicians with daily objective records of the patient’s compliance with prescribed exercise activities. This information helps clinicians maximize the benefits of training exercises and maintain patient motivation.
THE VALUE OF OBJECTIVE INFORMATION

INFORMATION VALUE

In today’s healthcare market, providers are adopting evidence-based clinical models in response to the demands of third party payers for more cost-effective services. A measurement tool is of clinical value when it provides new information and objective evidence for clinical decision-making, thereby directly impacting the treatment plan and resulting in an improved outcome. The objective information provided by NeuroCom assessments enhances care by providing objective inclusion/exclusion criteria, by improving care outcome, and by improving the efficiency of care.

OBJECTIVE INCLUSION/EXCLUSION CRITERIA

Patients with chronic disorders and their families frequently demand the maximum number of services, third party payers tend to withhold authorization for services, while care providers are caught in the middle. Objective allocation criteria aids in treatment planning and gets the patient into the appropriate level of care more quickly, reducing additional expenses due to “doctor shopping” and/or further deterioration due to fear, activity restriction, and deconditioning. Objective allocation of services also helps assure patients and their families that appropriate levels of care are being provided and justifies those services to the payers.

IMPROVING CARE OUTCOME

Outcome studies have clearly established that, for the appropriate patients, treatment plans customized to the individual patient’s pathology and impairments are more effective and result in better outcomes than generic treatment approaches. Impairment information is essential in the customized planning process because it directs the treatment of patients lacking definitive pathological diagnoses and indicates co-morbidities requiring modified or enhanced treatment plans for patients with pathological diagnoses. Finally, treatment outcomes are objectively demonstrated by documenting changes in impairments and functional limitations.

IMPROVING THE EFFICIENCY OF CARE

During the course of treatment, impairment and functional limitation information can more quickly identify patients who are not improving in accordance with the care plan. In these cases, the information helps define modifications or justifies changing the patient’s level of care. This type of progress monitoring has been a routine component of the customized treatment programs mentioned above.
SUMMARY

Chronic balance and mobility disorders can be effectively managed, and positive functional outcomes in this historically difficult patient population are attainable if properly diagnosed. The key is accurate information from the outset that includes pathology data, as well as critical assessments of impairments and functional limitations.

Treatment based on pathology alone may not result in resolution of a patient’s disorder in many cases. A clinician may know that a patient has a balance disorder through clinical observation alone or through the diagnosis of pathology. For those patients who have demonstrated balance problems, however, effective treatment requires a customized approach targeting the specific underlying sensory and motor impairments. Further, the clinician will need to measure the resultant functional impact, as this can vary considerably between patients with the same pathology. This integration of information enables the clinician to develop the most effective and efficient treatment plan for each patient.

The accuracy of assessment information provided by NeuroCom system protocols has been documented extensively within the published literature across a wide range of patient populations. The clinical literature has also shown NeuroCom measures to be sensitive to impairments associated with pathology and normal aging, as well as the improvements associated with rehabilitation. The test-retest reliability of the system measures is well established. The evidence supports the application and clinical value of the information provided by NeuroCom system assessment protocols to balance and mobility disordered patients.

By incorporating evidence-based practices within a multi-disciplinary team environment supported by qualified clinicians and the appropriate measurement tools and technology, enhanced treatment planning and improved functional outcomes will follow.


<table>
<thead>
<tr>
<th>Test</th>
<th>VSR®</th>
<th>BASIC Balance Master®</th>
<th>Balance Master®</th>
<th>PRO Balance Master®</th>
<th>SMART Balance Master®</th>
<th>SMART EquiTest®</th>
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</thead>
<tbody>
<tr>
<td>Sensory Organization Test (SOT)</td>
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<td>Head Shake-Sensory Organization Test (HS-SOT)</td>
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<td>modified Sensory Organization Test (mSOT)</td>
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**Training Protocols With Visual Biofeedback**

- Training for habituation and compensation on a fixed or moving surface
- Training for habituation and compensation in a fixed or moving visual environment
- Seated Balance Training
- Weight Bearing and Mobility Training
- Closed Chain Training
- Custom Training

Requires the Long Forceplate Option