# Dynamic Posturography Systems Necessary by All ENT Departments?

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12th Practical Approach to Vertigo

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# TERMS and DEFINITIONS

**Posturography** is a term consisting of all techniques that are used to quantify ability of postural control in upright stance in static and dynamic conditions.

**Computerized Dynamic Posturography (CDP)** is defined as a test protocol mainly comprised of Sensory Organization Test (SOT) and Motor Control Test (MCT).* Sometimes PER and ADT are added to this description. CDP disturbs the posture via a moving platform (base of support, support surface) and/or tilting visual surround.

**In Static Posturography**, the subjects is placed on a static force plate acting as force and movement transducer that detects body movements.

- ❖CDP is the gold standard in the management of the pts with dizziness, vertigo or disequilibrium of known or unknown etiologies.
- ❖It is also recognized as a necessary equipment in disability evaluation of the pts with chronic balance or dizziness disorders.
- ❖Helpful in diagnosis of suspected vestibular disorders

*Monsell EM, Furman JM, Herdman SJ, Konrad HR, Shepard NT. Computerized dynamic platform posturography. Otolaryngol Head Neck Surg. 1997;117(4):394-8.
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# QUANTIFYING BALANCE AND MOBILITY IMPAIRMENTS

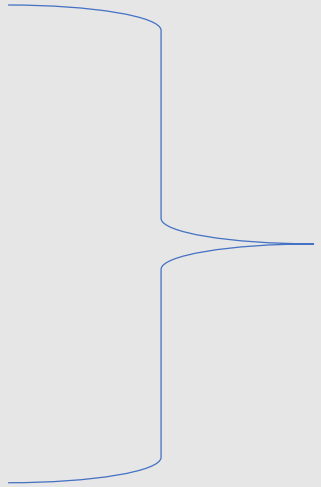
Assessment of impairments

**1-Sensory impairment assessment** evaluates pt.'s effective use of visual, vestibular and SS (support surface) info for balance control under variety of conditions

**2-Automatic motor impairment assessments** evaluate effectiveness of automatic and voluntary motor systems in controlling balance and mobility during a variety of static and dynamic tasks.

**3-Voluntary motor impairment assessments** evaluate effectiveness of voluntary motor systems in controlling balance and mobility during a variety of static and dynamic tasks.

**4-VOR impairment assessment** quantifies impact of a VOR lesion on pt.'s ability to maintain visual acuity and stable gaze while actively moving .



CDP

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# SENSORY IMPAIRMENT ASSESSMENT


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| TEST | SENSORY IMPAIRMENTS | CLINICAL APPLICATION |
|---|---|---|
| **SOT** | Postural control<br>Effective use of V, V, SS systems<br>Visual vestibular conflict resolution | Peripheral and central vestibular deficits<br>Post head injury<br>Fall risk<br>CNS movement dis.<br>Compensated peripheral vestibular deficits<br>Medical-legal |
| **HEAD SHAKE SOT** | Coordination of head movement and balance control<br>Balance control under dual-task conditions | Evaluation of higher performance capabilities<br>Compensated peripheral vest. deficits<br>Post BPPV evaluation |
| **MODIFIED SOT**<br>(does not include assessment of visual system) | Postural control<br>Effective use of Vestibular and SS systems | Peripheral and central vestibular deficits<br>Post head injury<br>Fall risk<br>CNS movement dis.<br>Compensated peripheral vestibular deficits |
| **MOD.CLINICAL TEST of SENSORY INTERACTION on BALANCE (MCTSIB)---**STATIC | Balance control under altered conditions | Identification of the presence of balance problems (does not isolate impairments in individual sensory systems) |

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# SENSORY ORGANIZATION TEST

This test objectively identifies abnormalities in 3 sensory systems, contributing to postural control. In the test, inaccurate info given to pt.'s eyes, feet and joints is controlled thru calibrated sway referencing of the support surface and/or visual surround.

By controlling sensory info visual and proprioceptive), it is possible to create sensory conflict situations, which investigates adaptive responses of CNS.


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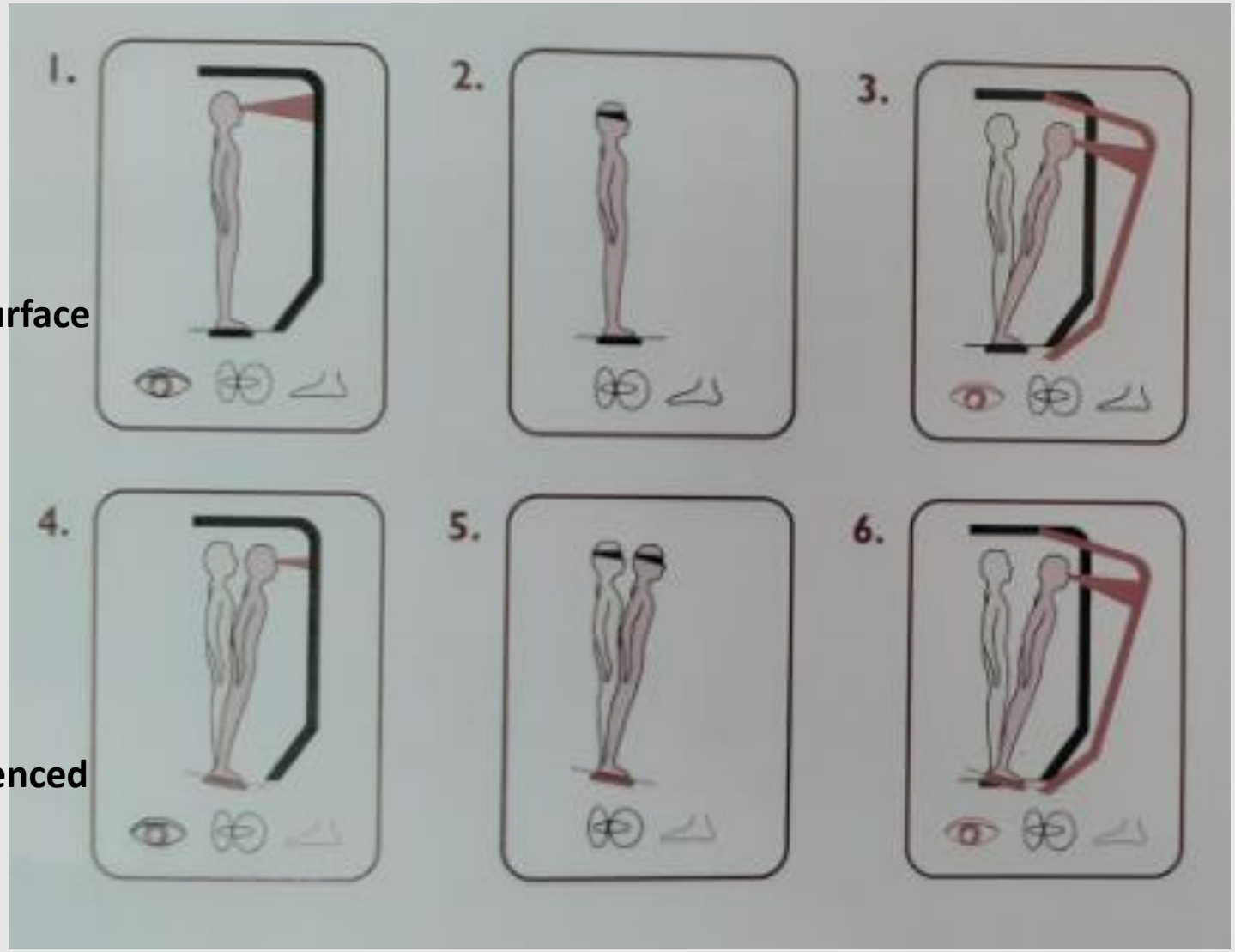
SOT protocol is comprised of 6 sensory conditions.

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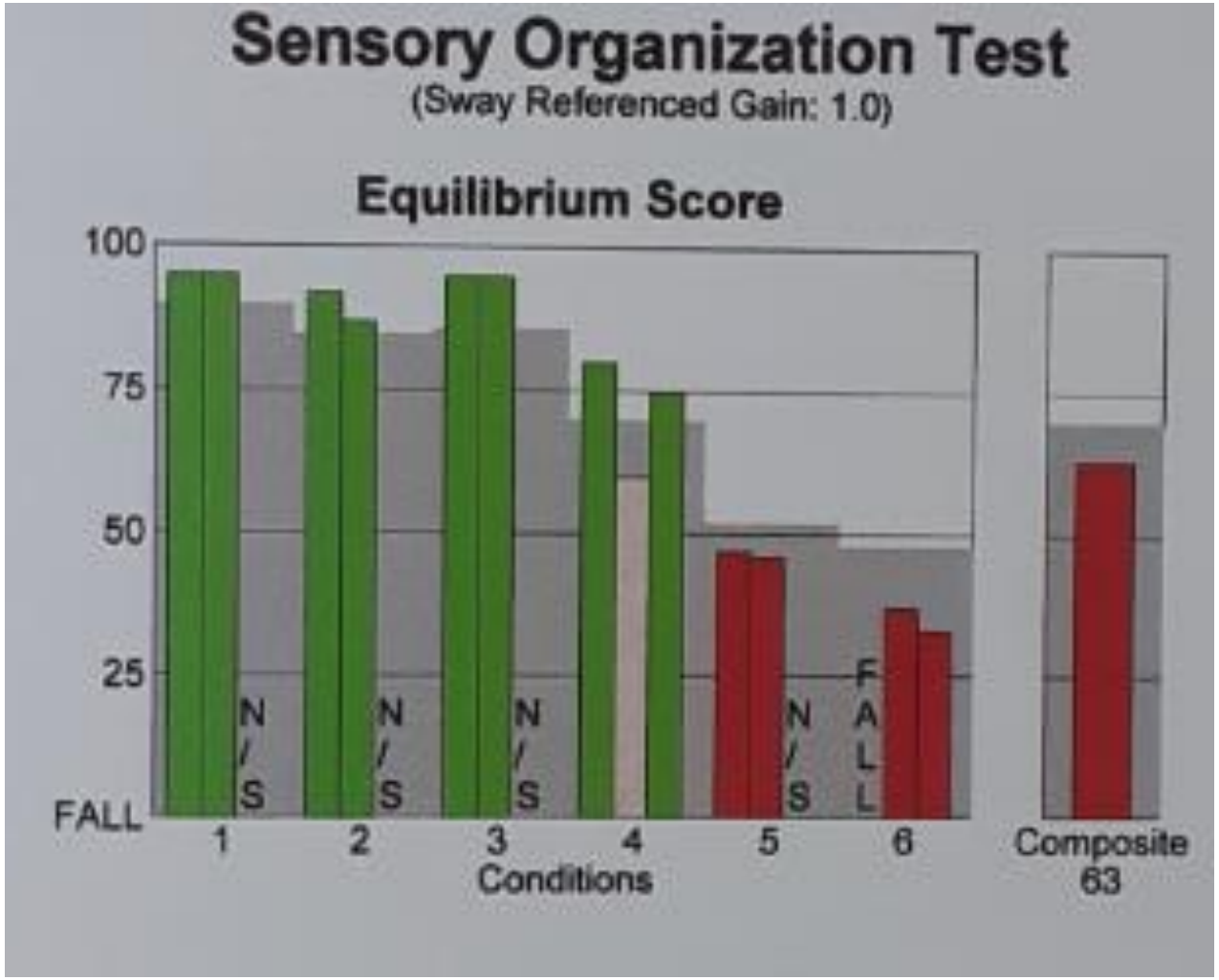
# Parameters in SOT

**1-Equilibrium score and composite score**: It quantifies COG sway under each of 6 sensory conditions. Effective use of each sensory input is determined on 6 conditions.

Composite equilibrium score characterizes overall level of performance. It is a weighted average of scores of 6 conditions

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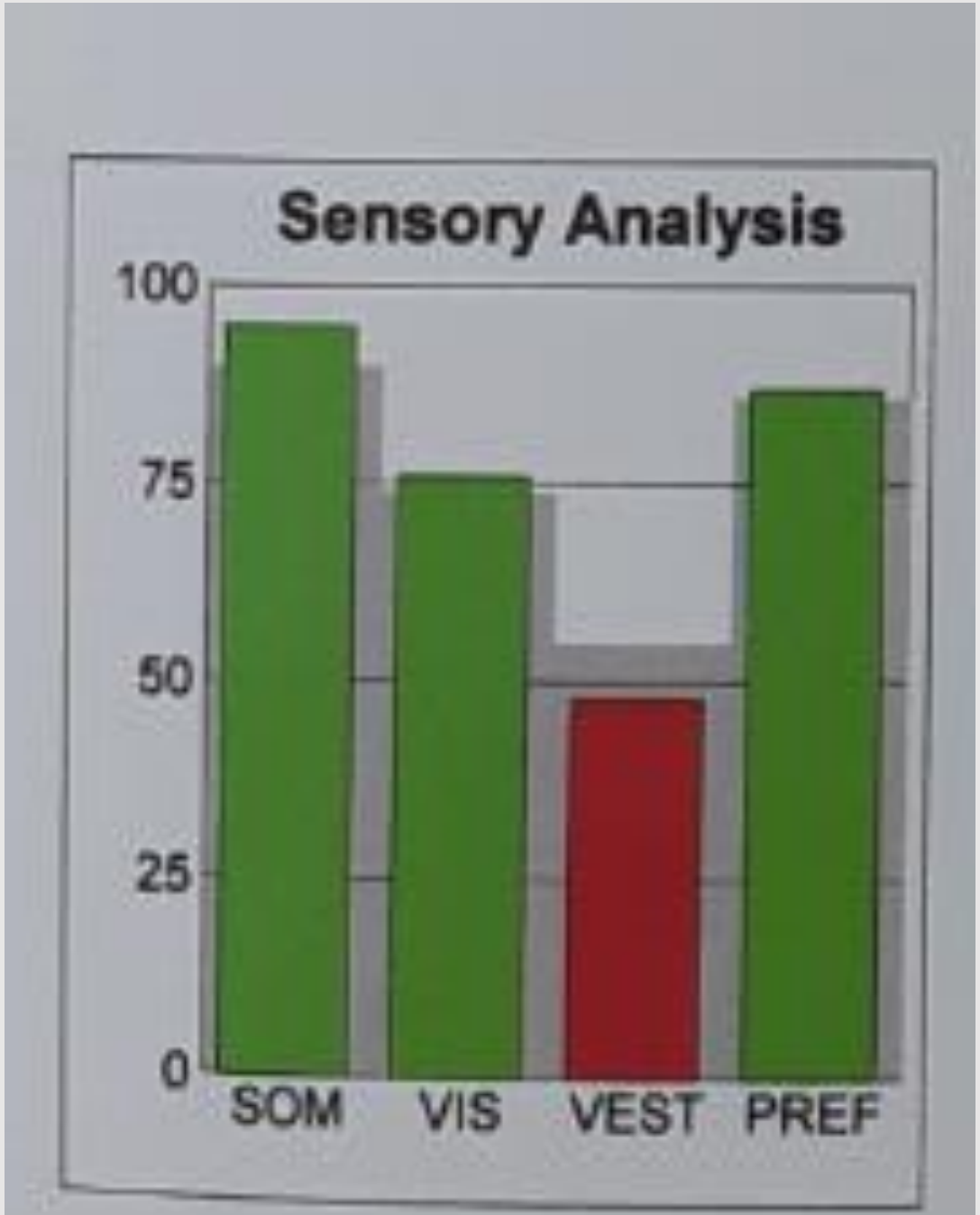
**2-Sensory analysis ratios** are used in conjunction with individual equilibrium scores in order to identify impairments of individual sensory systems.

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| SENSORY ANALYSIS RATIO | COMPARISON | FUNCTION TO BE MEASURED |
|---|---|---|
| SOMATOSENSORY (SOM) | Condition2/ Condition1 | Pt.'s ability to use SS input to maintain balance |
| VISUAL (VIS) | Condition4/ Condition1 | Pt.'s ability to use visual input to maintain balance |
| VESTIBULAR (VEST) | Condition5/ Condition1 | Pt.'s ability to use vest. input to maintain balance |
| PREFERENCE (PREF) | Condition3+6/ Condition2+5 | Degree to which a pt. relies on inaccurate visual info to maintain balance |

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# Dysfunction Patterns

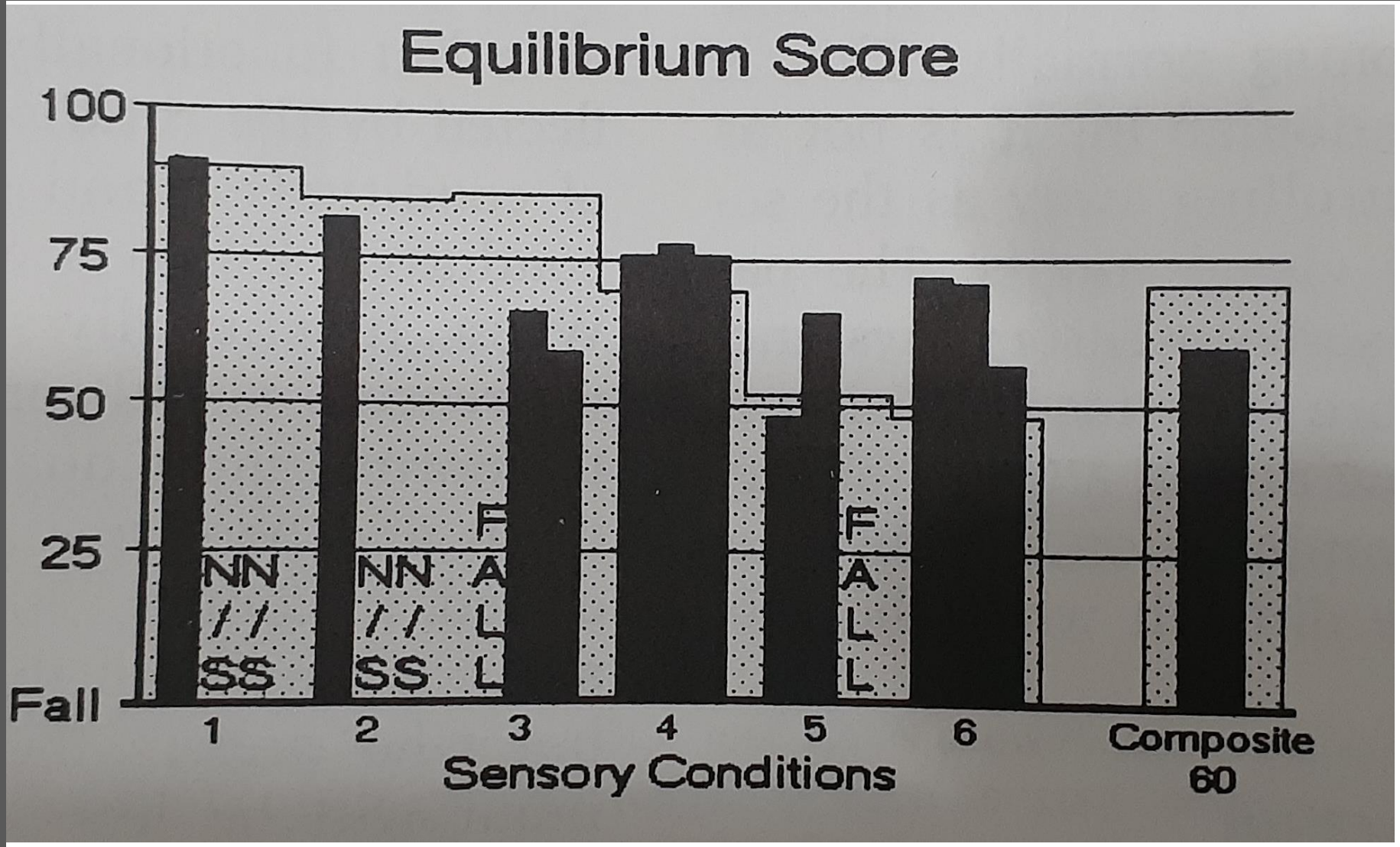
| Dysfunction Pattern | Failure/Low Score |
|---|---|
| **Vestibular dysfunction** | conditions 5, 6 |
| **Visual preference** | conditions 3, 6 |
| **Vestibular and visual dysfunction** | conditions 4,5,6 |
| **Vestibular and somatosensory dysfunction** | conditions 2,3,5,6 |
| **Vestibular dysfunction and visual preference** | conditions 3,5,6 |
| **Severe dysfunction** | failure >=4 conditions (3,4,5,6 or 2,3,5,6, or 1,2,3,4,5,6) |
| **Inconsistent** | scores in difficult conditions are better than those in easier tasks |

Telian SA. Invited Comment . Utility of posturography in management of selected conditions that cause dizziness. Am J Otol. 1997 ;18(1):113-124.

# Some Clues

- Vestibular dysfunction pattern only may not distinguish between peripheral and central vestibular lesions.
- SOT may not detect well-compensated unilateral vestibular lesions.
- SOT scores return to normal within 2 to 4 weeks of the initial insult.
- Abnormal visual preference, either alone or in combined with vestibular dysfunction is observed in pts with post-traumatic vertigo and in some elderly pts.

Nashner LM. CDP: Clinical Applications. In (Eds.) Jacobson GP, Newman CW, Kartush JM. Handbook of Balance Function Testing.Mosby Year Book 1993.




**Physiologically Inconsistent SOT Pattern**

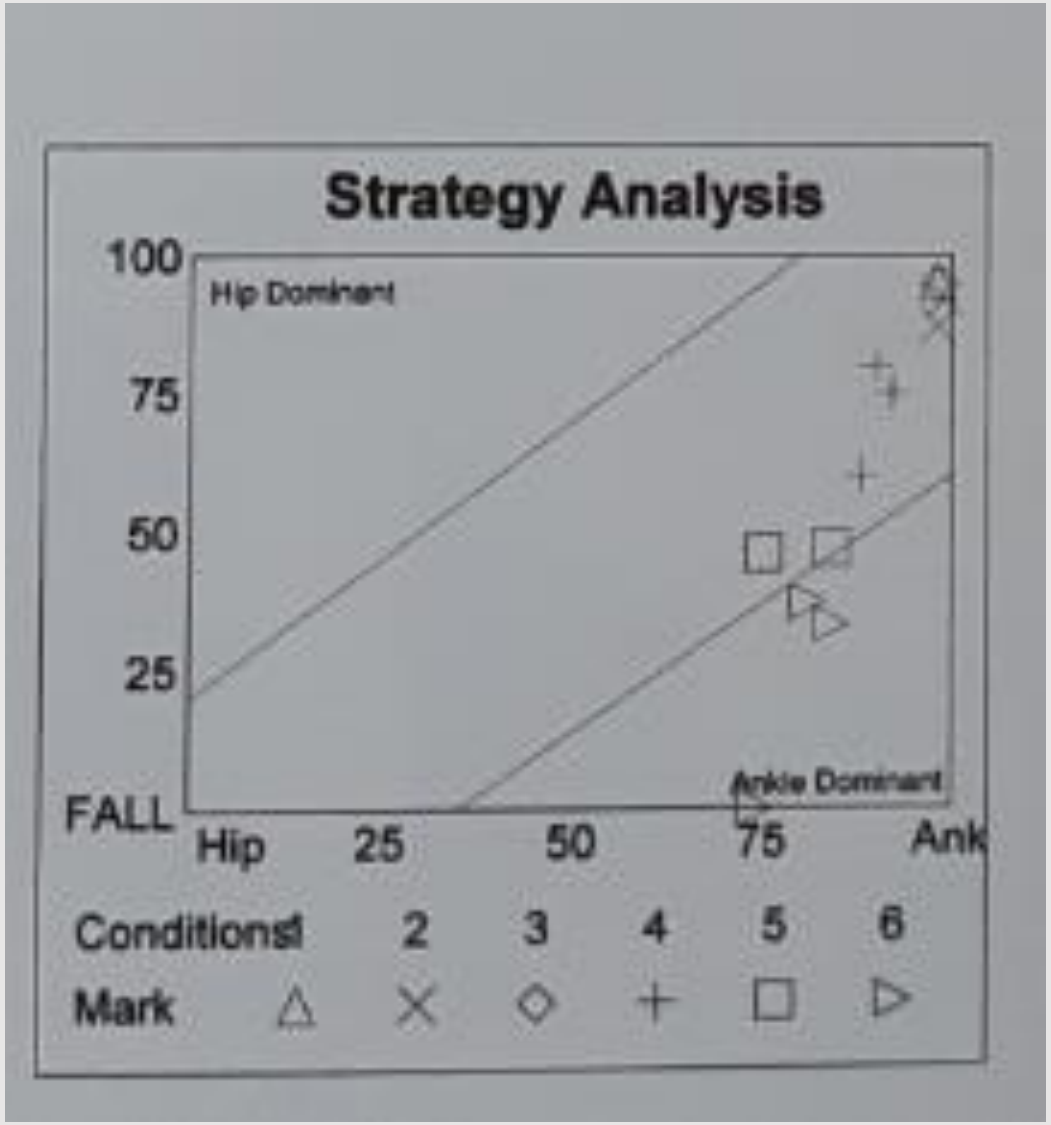
Nashner LM. CDP: Clinical Applications. In (Eds.) Jacobson GP, Newman CW, Kartush JM. Handbook of Balance Function Testing.Mosby Year Book 1993.

**3-Strategy analysis** quantifies amount of ankle (ankle strategy) and hip (hip strategy) movements to maintain balance during each trials.

Normal, stable subjects move primarily about ankle joints whereas they move hip joints as they become less stable.

If ankle strategy is used, score 100

hip strategy is used, score 0

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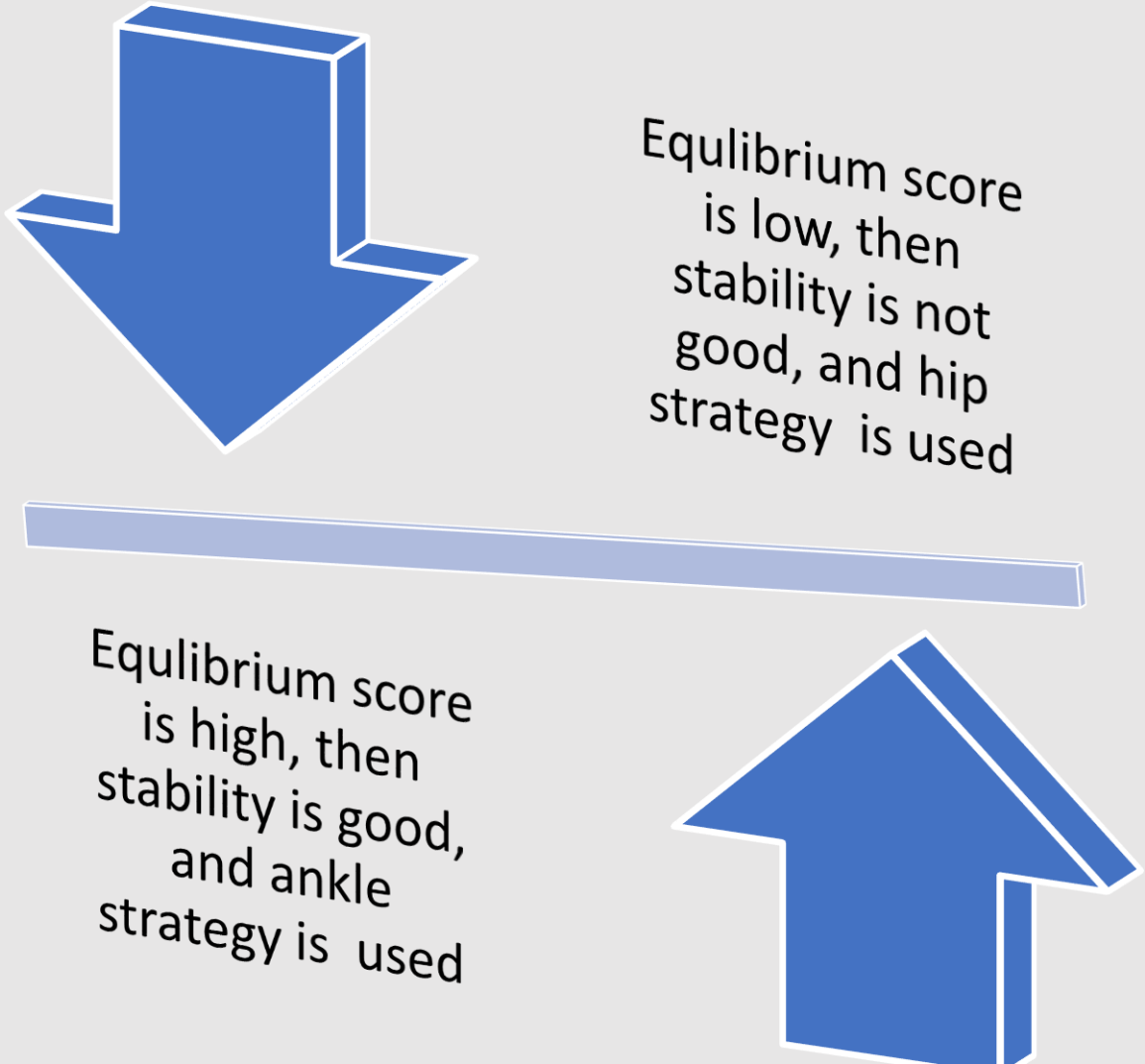
# Concordance among equilibrium score, select strategy and stability



**4-COG alignment** shows pt.’s COG position relative to center  of base of support.

It reflects pt.’s perception of verticality. Normal subjects can keep their COG near the center.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## Functional Considerations

Accurate organization of sensory info is critical to maintaining balance in variety of conditions in daily life.

An inability to organize sensory info appropriately results in instability, where

- visual cues are diminished (darkness),
- surface is unstable or compliant (sandy beach, boat deck) or
- conflicting visual stimuli (busy shopping mall, large moving objects) exist.

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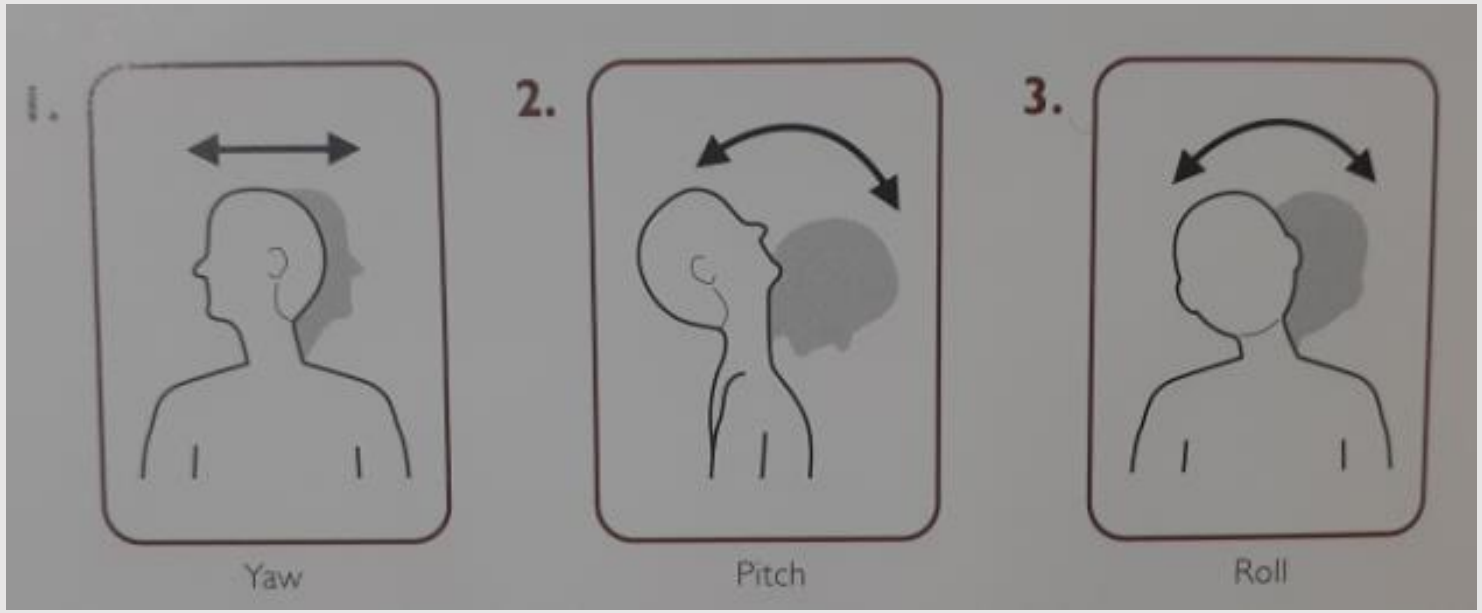
# HEAD SHAKE SENSORY ORGANIZATION TEST (HS-SOT)

This test is warranted when a symptomatic case can complete SOT with normal scores.

It identifies impairments in the pt.'s ability to effectively use vestibular inputs for balance while moving the head.

Abnormal HS-SOT scores can demonstrate the movement axes that present the maximum challenge to the pt. in daily life.




Movement Axes: R to L (horizontal), up and down (vertical), side to side (roll)

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The test includes SOT 2 and SOT 5 while the pt. wears a head movement monitor and performs continuous rhythmic head movement about a specified horizontal, vertical and roll axes.

The pt. is instructed to maintain frequency (one turn per second) and amplitude of movement (30 degrees in each direction for the hor. axis)

so that average velocity can be maintained at or above 80 degrees, 60 degrees and 60 degrees per second for horizontal, vertical and roll axes, respectively.

For each condition the pt. is given one unscored practice trial followed by up to 5 scored trials.

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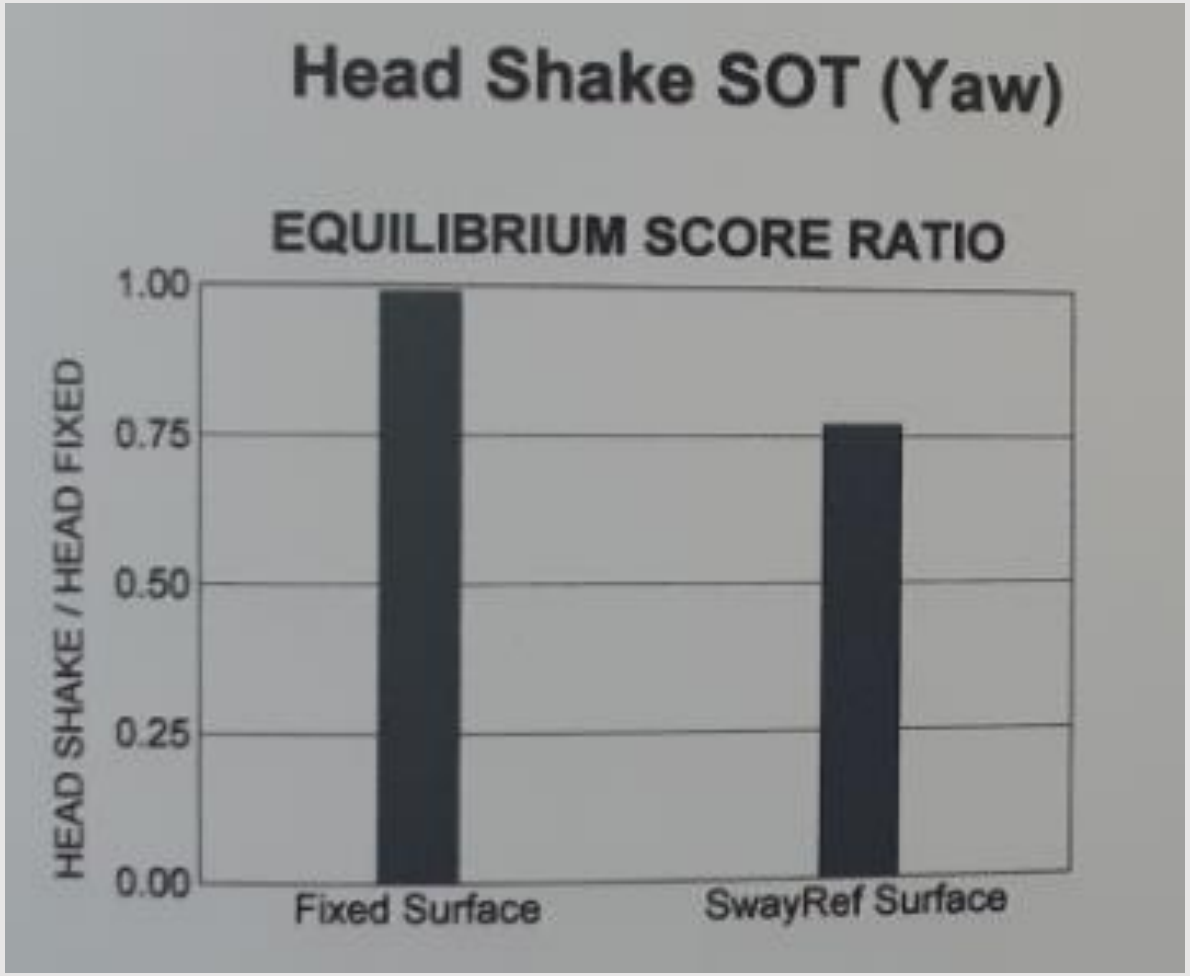
# Parameters in HS-SOT

**1-Equilibrium score ratio** is a number between 0 and 1 comparing the equibrium score of each head shake condition to the average score of the comparable condition performed with the head fixed.

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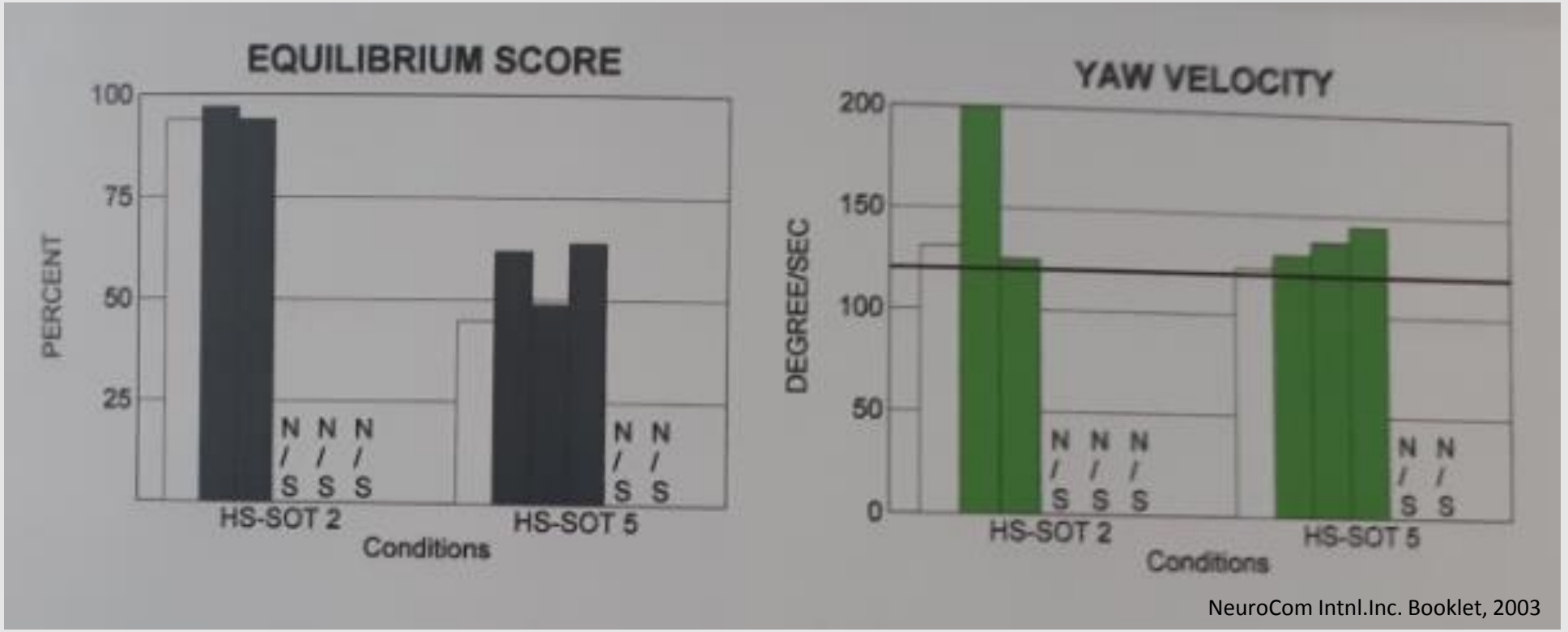
2- **Equilibrium score** graph displays individual raw equilibrium scores for SOT 2 and 5.

3- **Movement axis velocity** graph displays average head movement velocity scores for each of the selected head movement axis. A horizontal reference line compares the velocity scores to the required minimum velocity.

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# Functional Considerations

This test can quantify problems in pts. with subtle sensory problems who can obtain normal SOT scores.

It provides useful objective info regarding pt.'s ability to perform tasks in everyday life.

As HS-SOT brings additional challenges to the sensory organization of the balance, the equilibrium scores of normal subjects are slightly lower than SOT.

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## **There are two types of abnormality**:

**In first type**, stability is reduced under one or two HS conditions, and the required movement velocity is achieved.

**In second type**, the pt. maintains stability, but do so only by moving the head more slowly than the required minimum velocity.

Most of the pts. with UW of 25% or higher and normal SOT score had abnormal HS-SOT.

Majority of the pts. with motion provoked symptoms and normal SOT score had abnormal HS-SOT.

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# MODIFIED SENSORY ORGANIZATION TEST (mSOT)

This test provides info about interaction of 3 sensory systems. In the test, inaccurate info given to pt.'s feet and joints is controlled thru calibrated sway referencing of the support surface. It does not provide info on visual-vestibular conflict resolution.

**mSOT =SOT – Visual surround**


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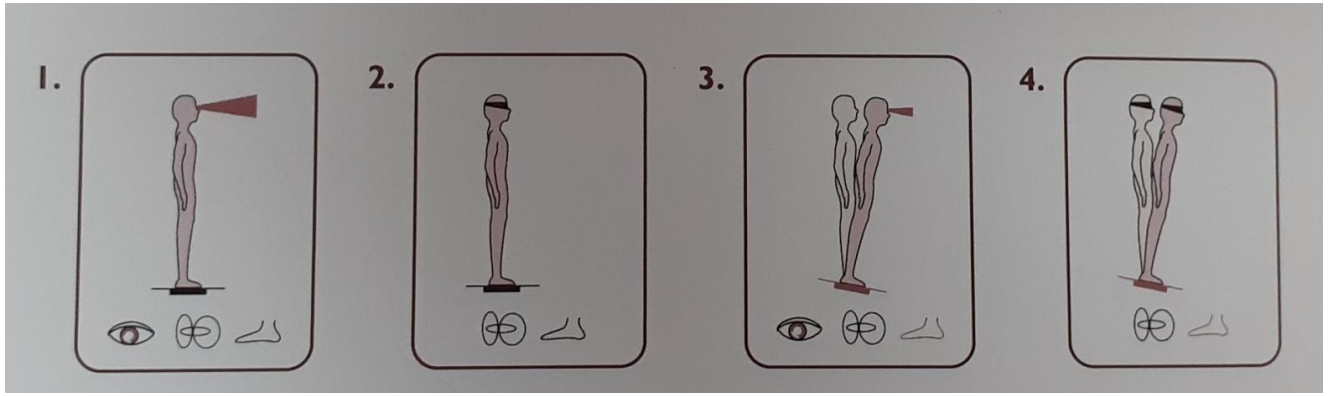
It measures how well a pt. can maintain postural stability under 4 sensory conditions.

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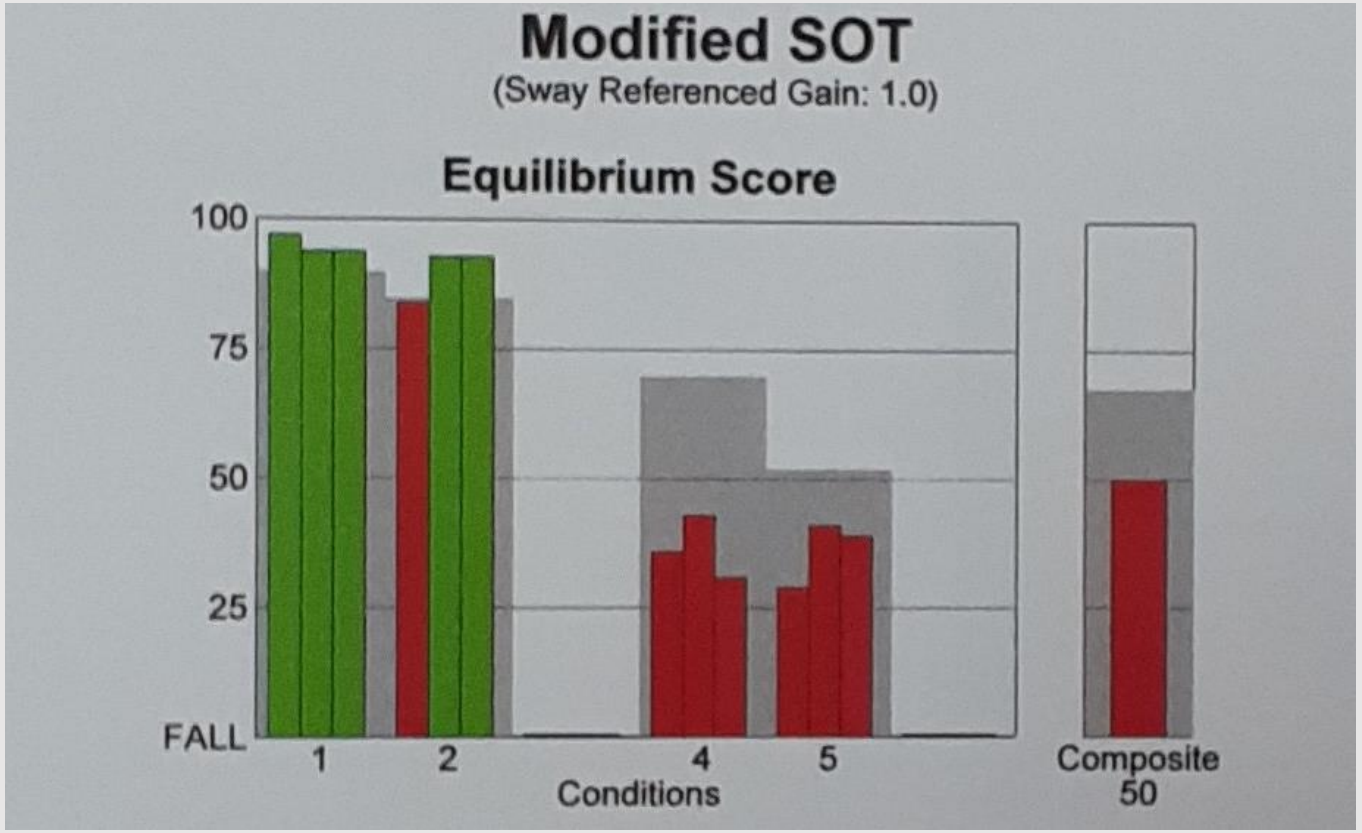
# Parameters in mSOT

**1-Equilibrium score** quantifies COG sway under each of 3 trials of 4 sensory conditions.

Effective use of individual sensory inputs is determined from overall pattern of scores on 4 conditions.

Composite equilibrium score, weighted average of scores of 4 conditions, characterizes overall level of performance.

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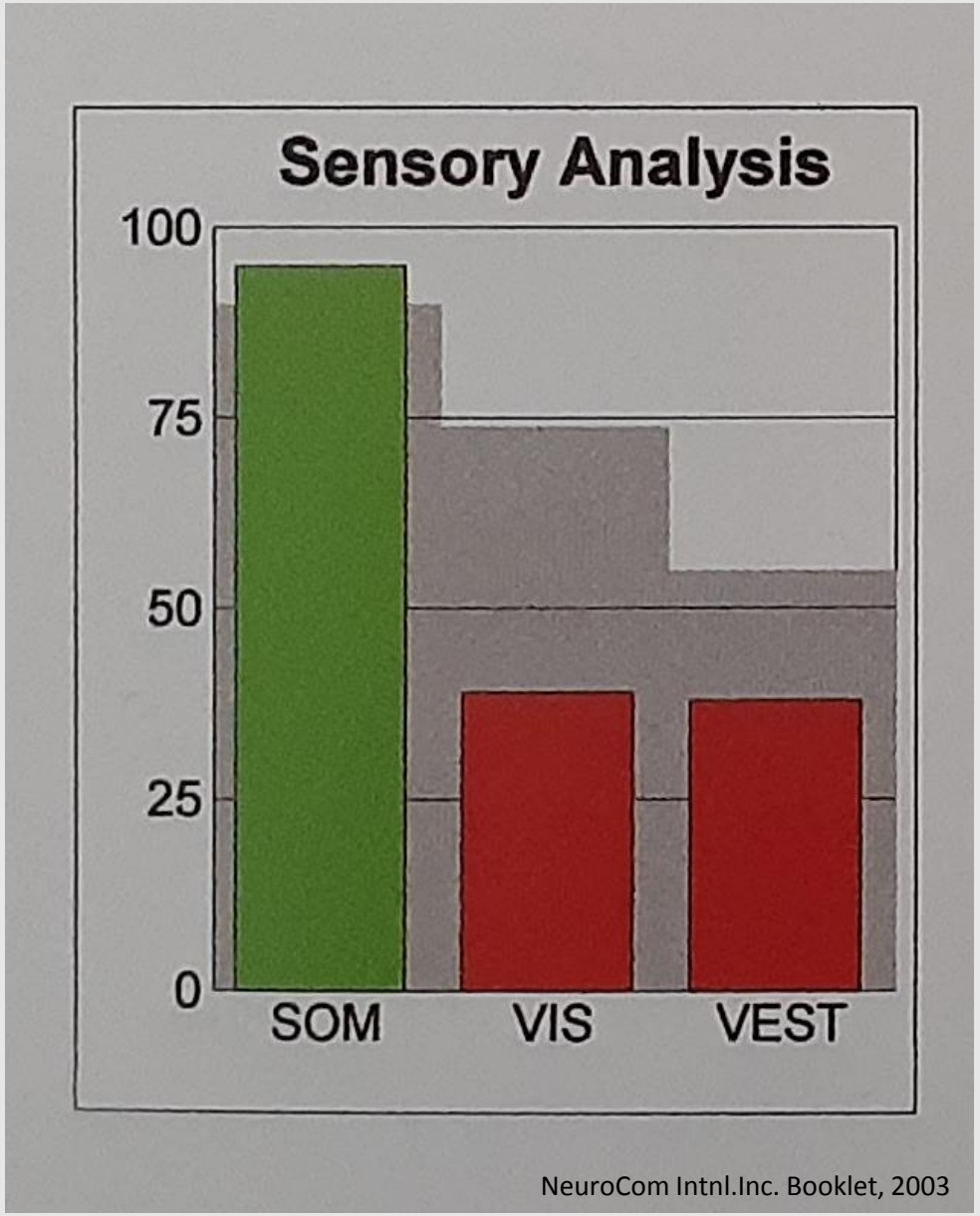
**2-Sensory analysis ratios** are used in conjunction with individual equilibrium scores in order to determine contribution of individual sensory systems.

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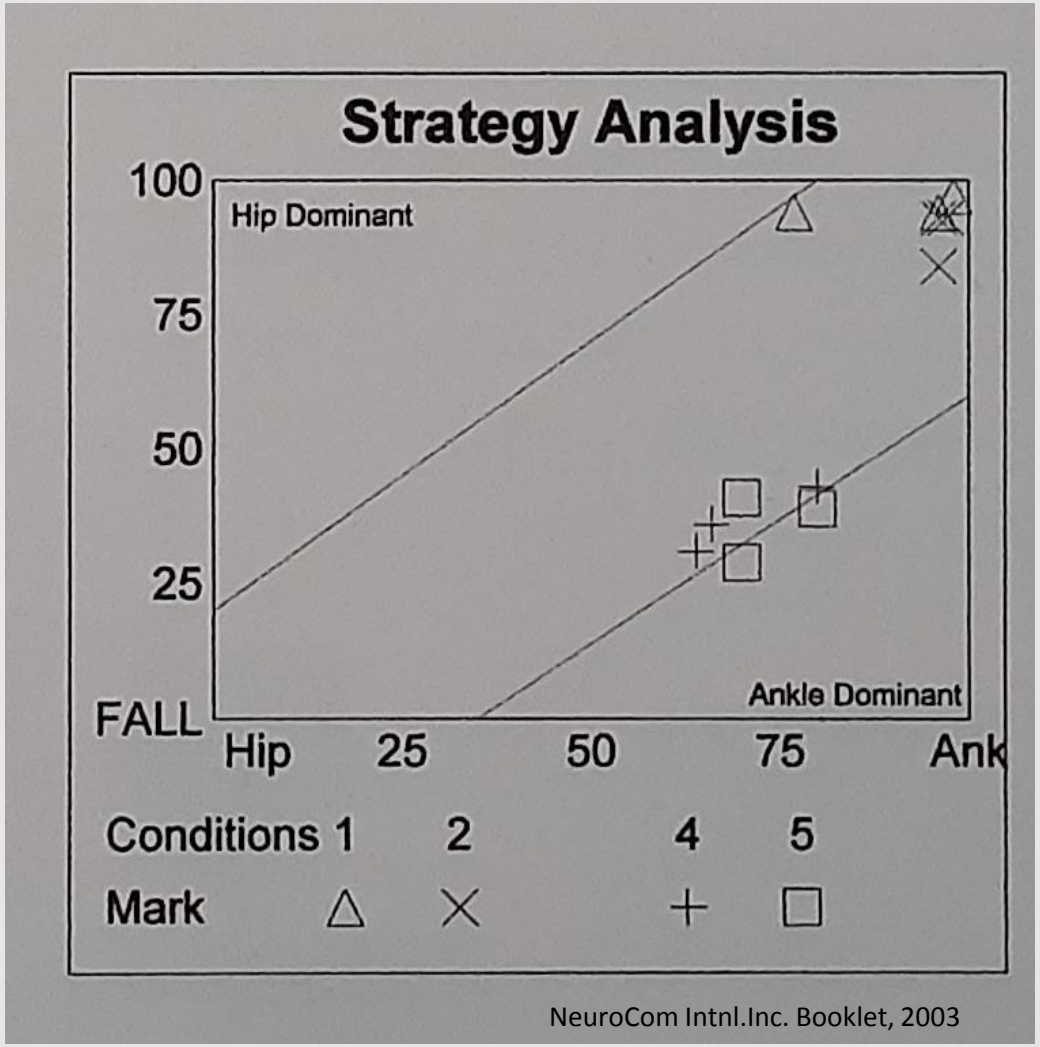


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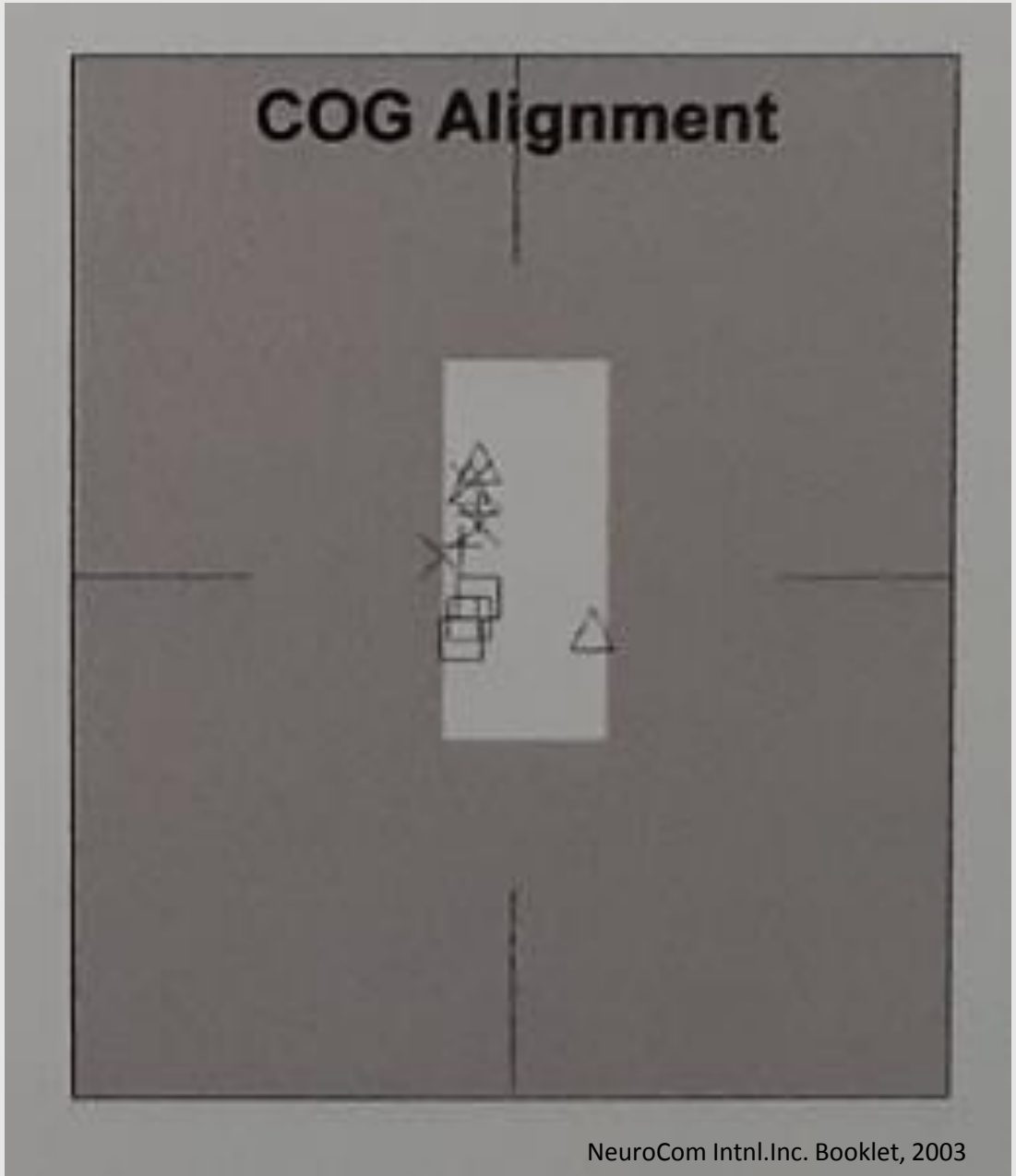
**4-COG alignment** shows pt.'s COG position relative to center of base of support.

Normal subjects can keep their COG near the center.

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## Functional Considerations

Accurate organization sensory info is critical to maintaining balance in variety of conditions in daily life. An inability to organize sensory info appropriately results in instability in environment where

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*surface is unstable or compliant (sandy beach, boat deck).

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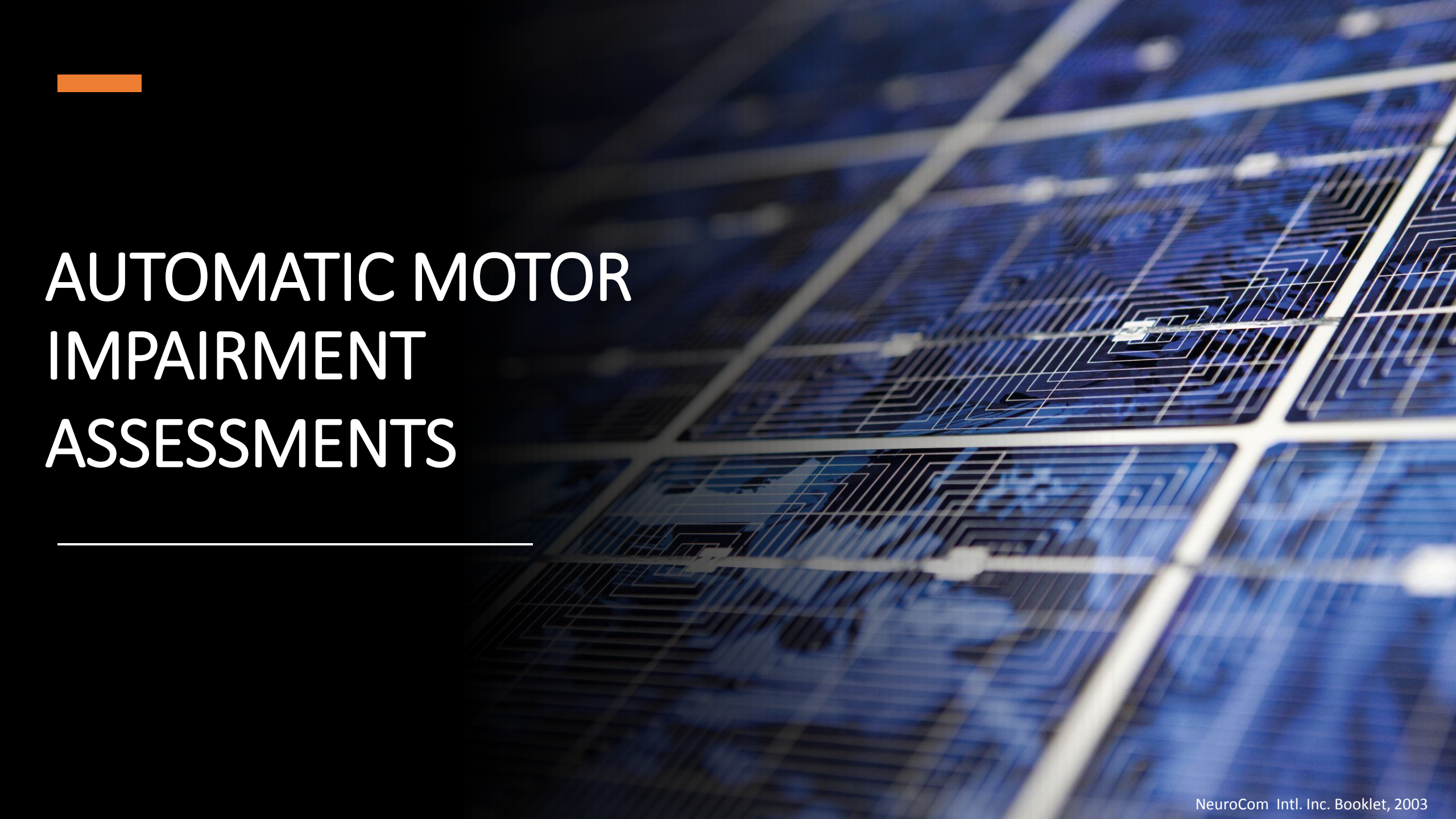
# AUTOMATIC MOTOR IMPAIRMENT ASSESSMENTS



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| TEST | AUTOMATIC MOTOR IMPAIRMENTS | CLINICAL APPLICATION |
|---|---|---|
| **MOTOR CONTROL TEST** | Automatic stabilizing response to external perturbation<br><br>Timing, strength, weight symmetry | CNS movement dis.<br>Metabolic diseases affecting balance<br>Medical-legal cases |
| **POSTURE EVOKED RESPONSE** | Deficits within pathways mediating automatic stabilizing responses<br><br>Latency, amplitude, peak, IEMG | Metabolic diseases affecting balance<br>Peripheral neuropathy<br>Degenerative CNS disease |
| **ADAPTATION TEST** | Response adaptation to irregular/varying support surface conditions<br><br>Ankle strength/range of motion | Fall risk (elderly, mobility disorders) |

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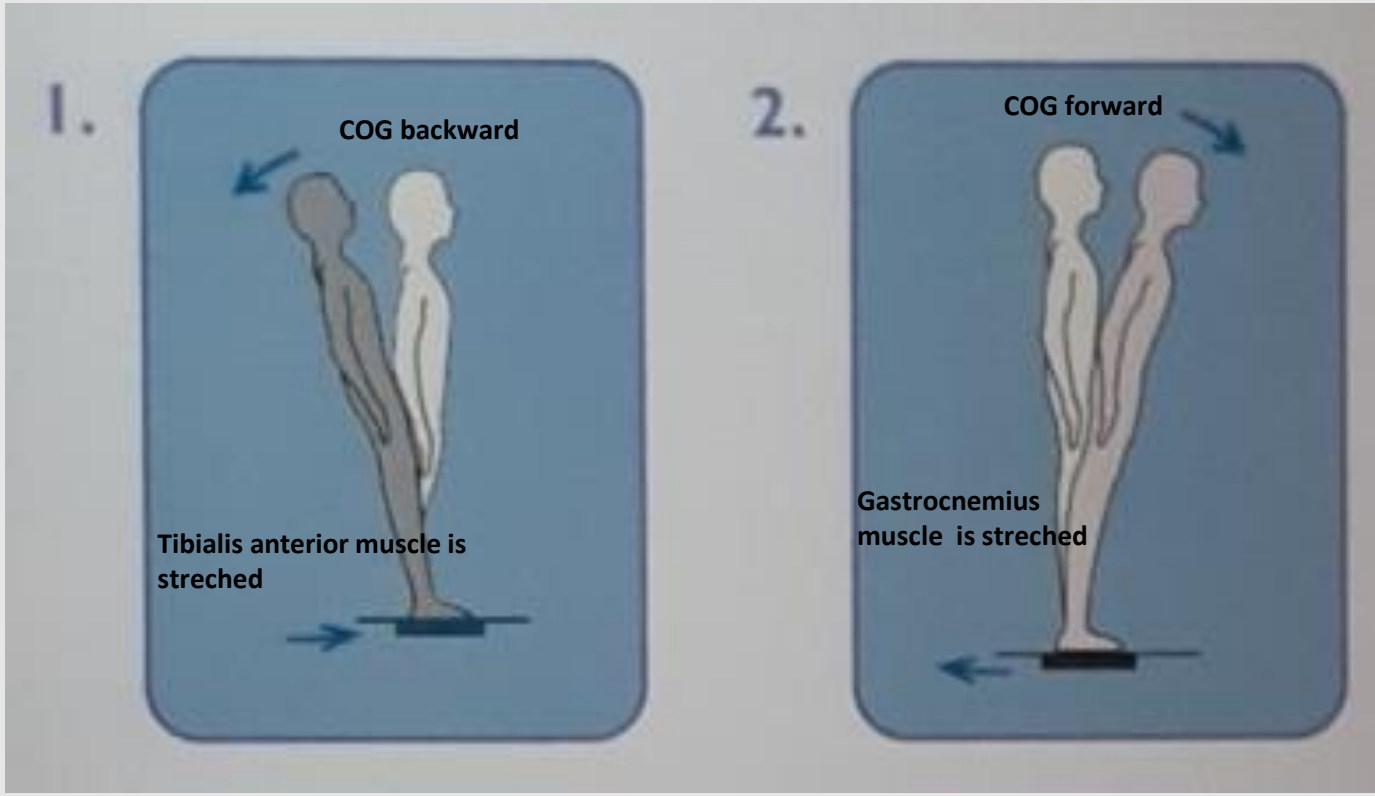
# MOTOR CONTROL TEST (MCT)

It assesses ability of automatic motor system to quickly recover following an unexpected external disturbance.

A series of medium and large platform translations in forward and backward directions elicit automatic postural responses.

Translations of the surface in one horizontal direction results in displacement of the COG in the opposite direction. To restore normal balance, a quick movement of COG back to the center is required.

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Support surface translation rotates the body about the ankle joints at a speed ranging between $3^0$ and $8^0$/sec.

At these speeds, SL responses are seldom observed.

The earliest responses are equivalent to LL that is observed in PER test.

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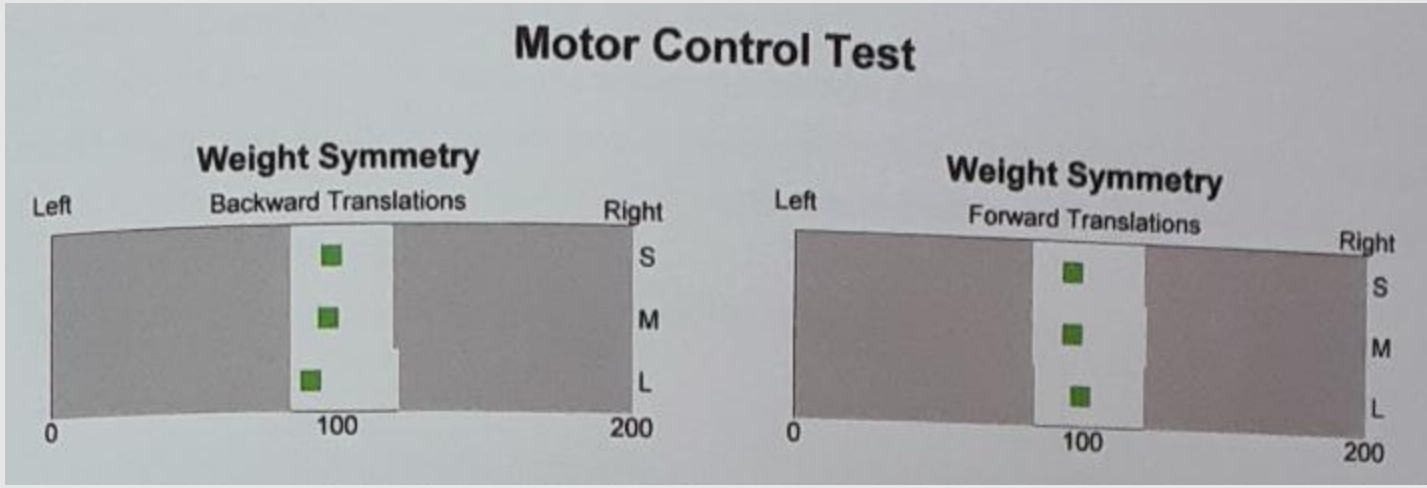
# Parameters in MCT

1-**Weight symmetry** quantify relative distribution of weight on each leg.

Accurate interpretation of latency and amplitude scaling measures requires weight-bearing symmetry within normal limits.

Automatic responses may be suppressed in a leg not carrying weight.

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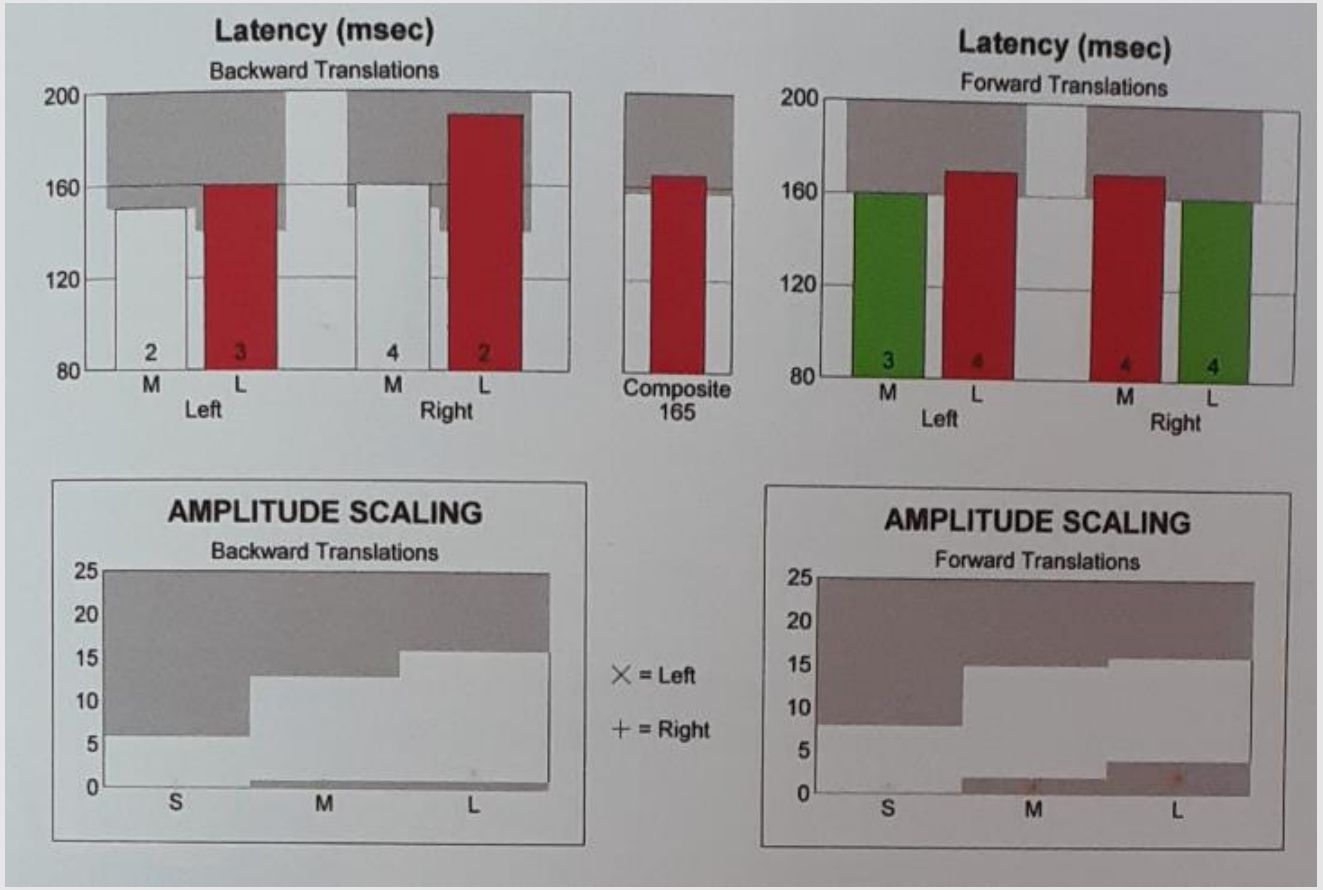
2- **Latency** quantifies time between stimulus onset and initiation of the pt.'s response.

Composite latency score is an average of individual score for 2 legs.

Latencies are expected to be shorter for large translations than for medium translations in normals.

3- **Amplitude scaling** measures strength of response for both legs and for 3 translation sizes.

Strengths are expected to be similar for both legs and to increase as size of translation increases.

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# Functional Considerations

Automatic postural responses are 1st line of defense against a fall following unexpected external disturbances to balance.

MCT in combined with SOT is useful in differentiating true pathologic conditions and exaggerated sway responses from normal responses.

Since they are not under conscious control, automatic responses are initiated very rapidly. They are highly repeatable across trials.

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Exaggerated responses are volitional, take longer to intiate, and tend to vary widely from one trial to the next. Therefore, automatic and volitional (exaggerated) responses can be readily distinguished within MCT data.

**Automatic response latency is important for diagnostic process. Prolonged latency is a strong evidence of musculoskeletal or biomechanical problems in long loop pathways including peripheral nerves, ascending and descending pathways and brain.**

**In case of prolonged latency in MCT, EMG protocol/PER test is warranted in further localizing deficit in peripheral nerve and central pathways.**

Lawson GD, Shepard NT, Oviatt DL, Wang Y. Electromyographic responses of lower leg muscles to upward toe tilts as a function of age. J Vestib Res. 1994;4(3):203-14.

- **Bilateral and bidirectional prolonged MCT latencies** are most likely the results of global CNS deficits such as MS, polyneuropathy and neurotoxic exposure.

- **Unilateral prolonged MCT latencies** are indicative of localized CNS lesions which may be peripheral (orthopedic nerve problems) or central (brain stem stroke).

- **Unidirectional prolongations** are caused by CNS deficits localized to efferent branches of the long loop system.

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# Utility of MCT and SOT

| | Applications | |
|---|---|---|
| Test Modality | Diagnostic | Functional |
| Response latencies | Peripheral nerve, spinal cord, and brain stem lesions | None documented |
| Response strengths | Cerebellar deficits (muscle weakness, nerve injuries) | Automatic motor adaptation |
| Sensory organization test patterns | Vestibular system dysfunction, positive evidence for symptoms exaggeration | Overall balance and sensory adaptive capabilities |
| Strategy analysis | None documented (ankle muscle weakness, distal sensory losses) | Movement control adaptive capabilities |
| Center of gravity alignment | None documented (reduced range) | Perception of vertical |

Nashner LM. CDP: Clinical Applications. In (Eds.) Jacobson GP, Newman CW, Kartush JM. Handbook of Balance Function Testing.Mosby Year Book 1993.

# Diagnostic Decision Matrix

| Vestibular Function Tests | CDP TEST RESULTS | | | | |
|---|---|---|---|---|---|
| | Normal | Vestibular Dysfunction | Multisensory Dysfunction | Prolonged Latencies | Physiologically Inconsistent |
| Normal | Normal | Central vestibular | Central vestibular | Spinal/brain stem | Normal |
| Peripheral vestibular | Peripheral vestibular (compensated) | Peripheral vestibular (uncompensated) | Peripheral and central vestibular | Peripheral vestibular and spinal/brain stem | Exaggerating symptoms |
| Central vestibular | Central vestibular | Central vestibular | Central vestibular | Central vestibular and spinal/brain stem | Exaggerating symptoms |

Nashner LM. CDP: Clinical Applications. In (Eds.) Jacobson GP, Newman CW, Kartush JM. Handbook of Balance Function Testing.Mosby Year Book 1993.

# POSTURE EVOKED RESPONSE (PER)

It is a kind of EMG analysis.

It analyzes responses of gastrocnemius and tibialis muscles consisting of a freely standing pt.'s automatic reaction to an unexpected external balance perturbation.

There are 3 components of PER: short latency (SL), medium latency (ML) and long latency (LL) responses.

In pts. with prolonged MCT response, latency info. differentiates between peripheral and central causes. Thus, PER is warranted in cases with suspected CNS deficits affecting peripheral and/or central sensorimotor pathways innervating lower extremities.

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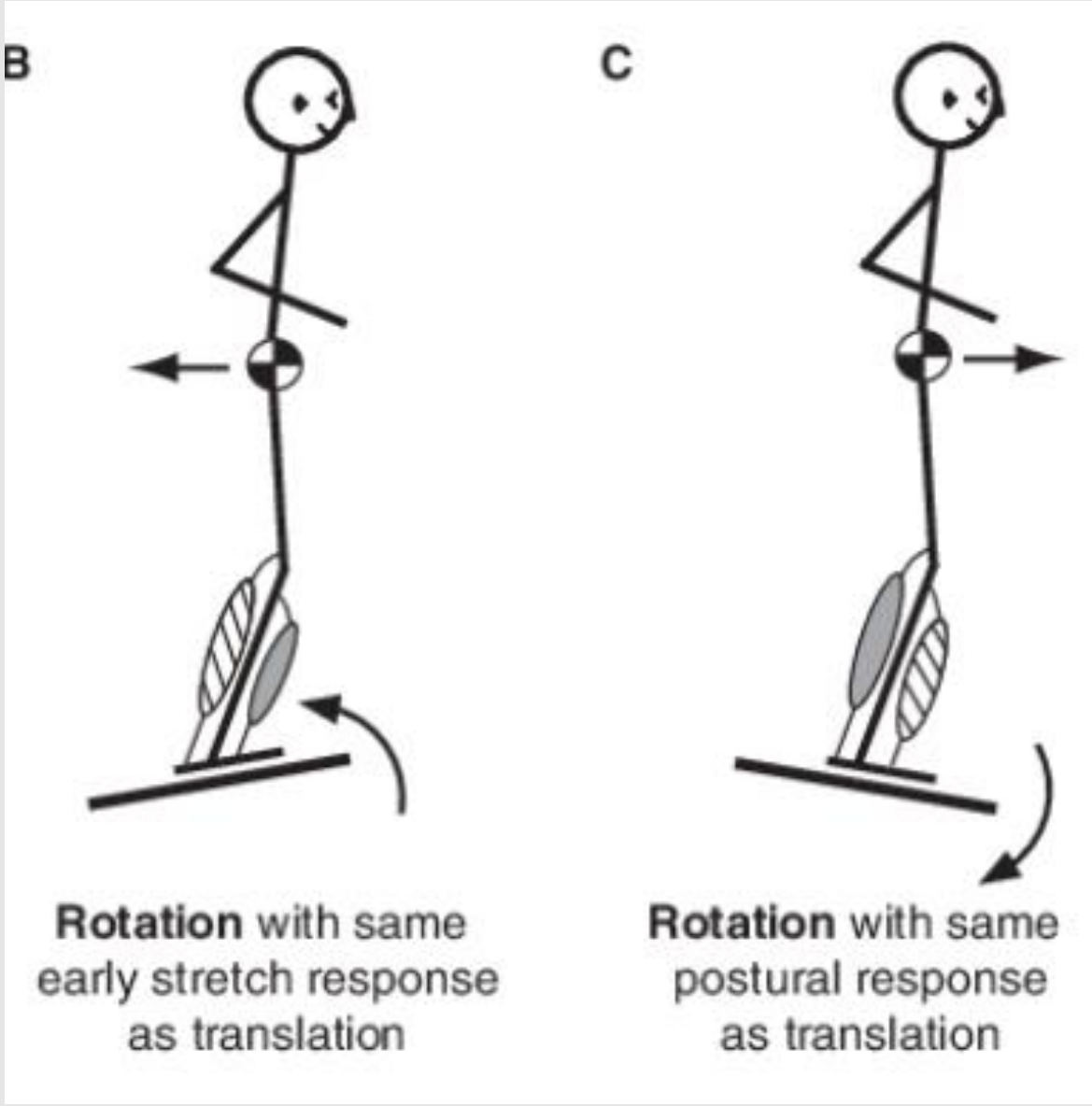
A series of 10 to 20 toes up and toes down surface rotations are used to elicit response.

Support surface rotations are delivered in a randomly timed manner.

High velocity support surface rotation (50 $^{0}$ /sec for 80 msec)

Raw EMG is sampled at 1,000 Hz. Waves are rectified and averaged. Operator may selectively remove raw EMG signals of individual muscles among 20 responses when necessary.

The operator labels response onset and termination.




Lena H. Ting. Dimensional reduction in sensorimotor systems: a framework for understanding muscle coordination of posture. P. Cisek, T. Drew & J.F. Kalaska (Eds.) Progress in Brain Research, Vol. 165

PER analyzes automatic response by quantifying contractile activities of extensor and flexor muscles of ankle joint elicited by rapid toes-up or toes-down rotations of support surface.

These contraction activities are recorded from surface EMG electrodes placed on gastrocnemius and tibialis anterior bilaterally.

**SL and ML** serve to exaggerate COG sway disturbance.

**LL** has an ankle stabilizing effect.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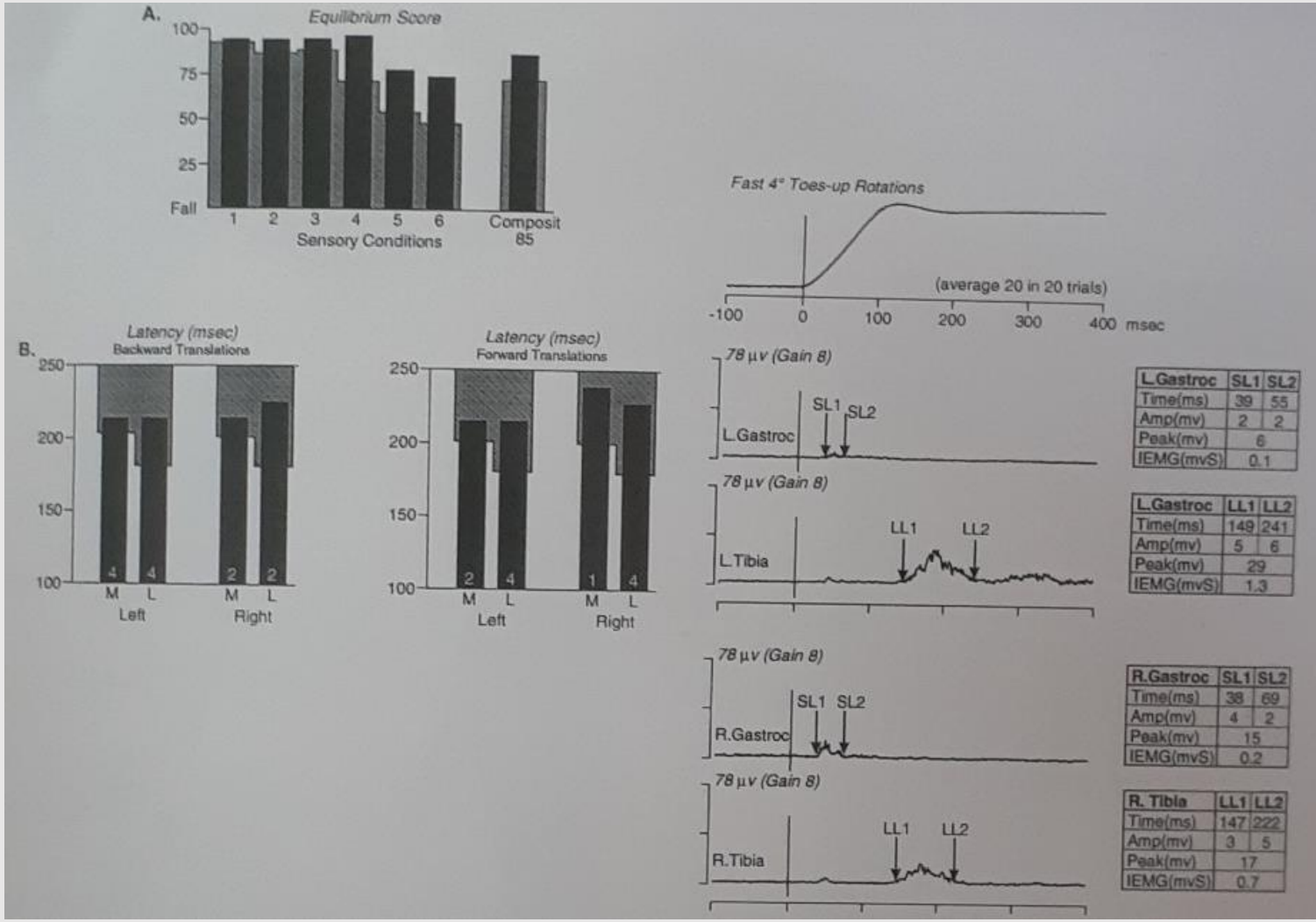
# Parameters in PER

1- **Latency** quantifies the time in ms between stim.onset and muscle activation. Latencies are measured for SL, ML and LL components of automatic response.

2-**Amplitude** measures magnitude of EMG signal in microvolts for each SL, ML and LL responses.

3-**Peak** quantifies maximum amplitude (in microvolts) of EMG signal between response onset and termination.

4-**IEMG** quantifies the integrated area under EMG signal (in units of microvolt-seconds) between response onset and termination.




| L.Gastroc | SL1 | SL2 |
|---|---|---|
| Time(ms) | 39 | 55 |
| Amp(mv) | 2 | 2 |
| Peak(mv) | 6 | |
| IEMG(mvS) | 0.1 | |

| L.Gastroc | LL1 | LL2 |
|---|---|---|
| Time(ms) | 149 | 241 |
| Amp(mv) | 5 | 6 |
| Peak(mv) | 29 | |
| IEMG(mvS) | 1.3 | |

| R.Gastroc | SL1 | SL2 |
|---|---|---|
| Time(ms) | 38 | 69 |
| Amp(mv) | 4 | 2 |
| Peak(mv) | 15 | |
| IEMG(mvS) | 0.2 | |

| R. Tibia | LL1 | LL2 |
|---|---|---|
| Time(ms) | 147 | 222 |
| Amp(mv) | 3 | 5 |
| Peak(mv) | 17 | |
| IEMG(mvS) | 0.7 | |

Four-averaged EMG signal with onset and termination marks

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# PER Results in Controls and Abnormal Results

- Average latency of SL is **32 msec**. Variations are less than a few msec.
- ML responses cannot be identified in all subjects. Average latency of ML of gastrocnemium muscle is **80 msec**.
- Following toes up rotation, LL is recorded from tibialis anterior muscle of both legs. Average latency is **110 msec**. It provides postural stability. It is not local stretch input. It is thought to be equivalent to the automatic postural responses that are the main line of defense against many types of unexpected postural disturbances.
- Delayed latencies are considered abnormal

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# Functional Considerations

- Studies imply that PER can differentiate spinal cord, brainstem, cerebellum, sensory motor cortex and internal capsule lesions.
- It may also differentiate demyelinating disorders from Parkinson's disease.
- Differentiation at this sensitivity is not the case for MCT.

Neurocom Intrnl Inc. Booklet 2003

## Clinical Interpretation of Posture-Evoked Response Patterns

| Pathology Type and Distribution | Latency Pattern | | |
|---|---|---|---|
| | Short Latency | Medium Latency | Long Latency |
| Peripheral nerve, nerve roots L5, S1: unilateral | Prolonged unilateral | Prolonged unilateral | Normal |
| Polyneuropathy demylination: bilateral | Prolonged bilateral | Prolonged bilateral | Normal (occasionally prolonged) |
| Spinal cord, brain stem, pyramidal tract, thalamus, cortex: unilateral | Normal | Normal | Prolonged unilateral |
| Spinal cord, brain stem, pyramidal tracts, thalamus, cortex: bilateral | Normal | Normal | Prolonged bilateral |
| Multilevel: bilateral | Prolonged bilateral | Prolonged bilateral | Prolonged bilateral |
| Cerebellar | Normal | Normal | Normal |

Nashner LM. CDP: Clinical Applications. In (Eds.) Jacobson GP, Newman CW, Kartush JM. Handbook of Balance Function Testing.Mosby Year Book 1993.

# ADAPTATION TEST (ADT)

It assesses pt.’s ability to minimize sway when exposed to surface irregularities and unexpected changes in support surface inclination.

A series of 5 platform rotations in toes-up or toes-down direction elicit automatic motor responses. In contrast to PER test, the rotations are slow ($8^{0}$/sec). These slower stimulus rotates the ankle joints at velocities similar to those generated in MCT.

For each platform rotation trial, a sway energy score measures magnitude of force response required to overcome induced postural instability.

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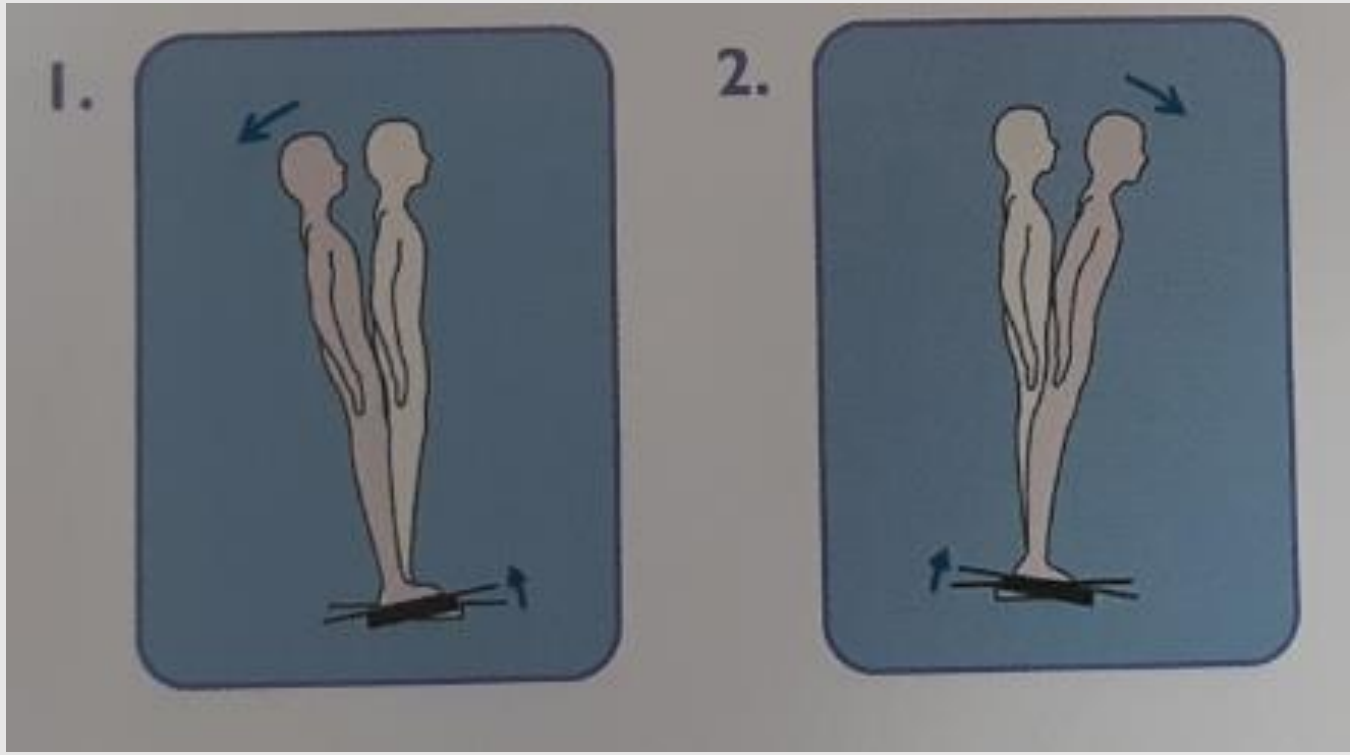
Unexpected toes-up and toes-down rotations elicit automatic responses, which tend to destabilize pt.’s balance.

During 1st unexpected trials, initial disruptive responses are corrected by secondary responses in opposite muscles.

With each subsequent trial, initial reactions are attenuated and secondary responses strengthened to reduce overall sway.

Performance on ADT necessitates an appropriate ankle movement, muscle strength and effective motor adaptation.

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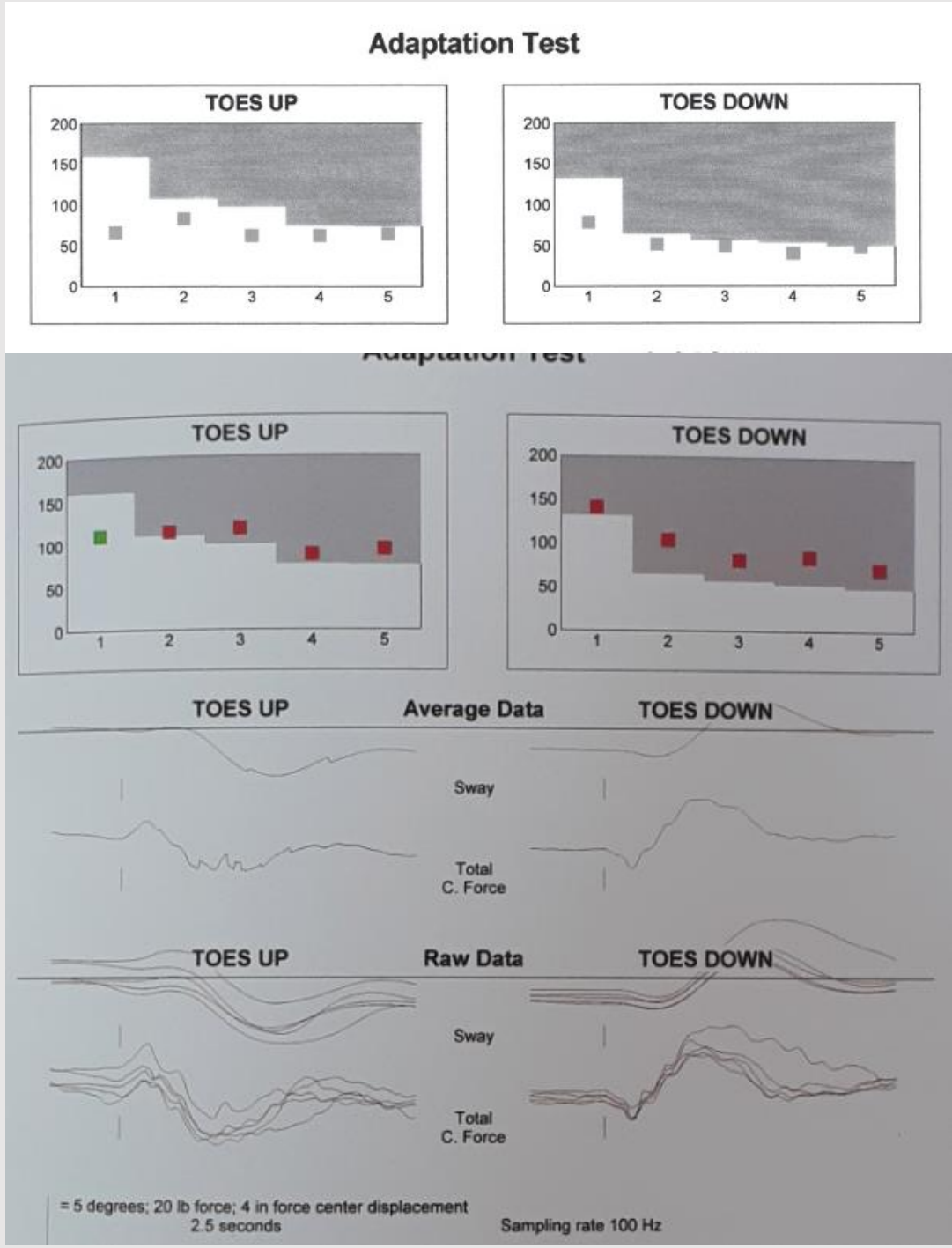
# Parameters in ADT

1- **Magnitude of force response** is a response to overcome sway induced by a series of toes-up and toes-down rotations

2-. **Averaged and raw sway data**

Normal subjects may or may not show increased sway responses to initial (trial 1) rotations. In either case, sway responses subsequent to the 1 st trial will be small in normal subjects.

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# Functional Considerations

Surface irregularities and changes in inclination of the support surface are common in daily life. Pts. with abnormal ADT results tend to have difficulty in daily life conditions.

ADT difficulties can arise from one or a combination of 2 causes:

The pt. may not suppres inappropriate automatic reactions. And/or

The pt.may have ankle joint weakness and restricted range of motion.

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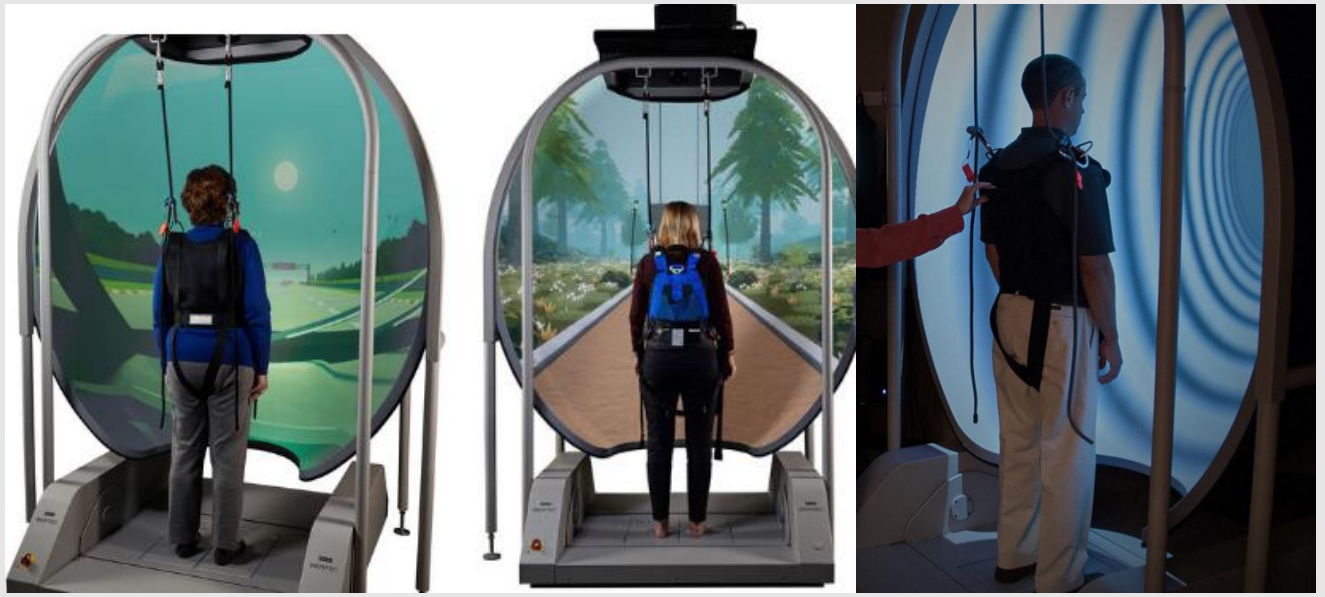
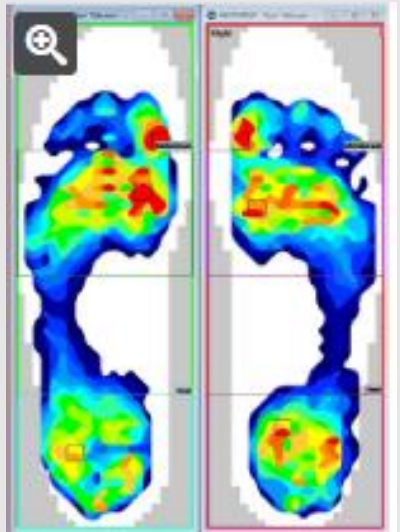
# RECENT DEVELOPMENTS

CDP +  virtual reality

Enriched visual stimulus types



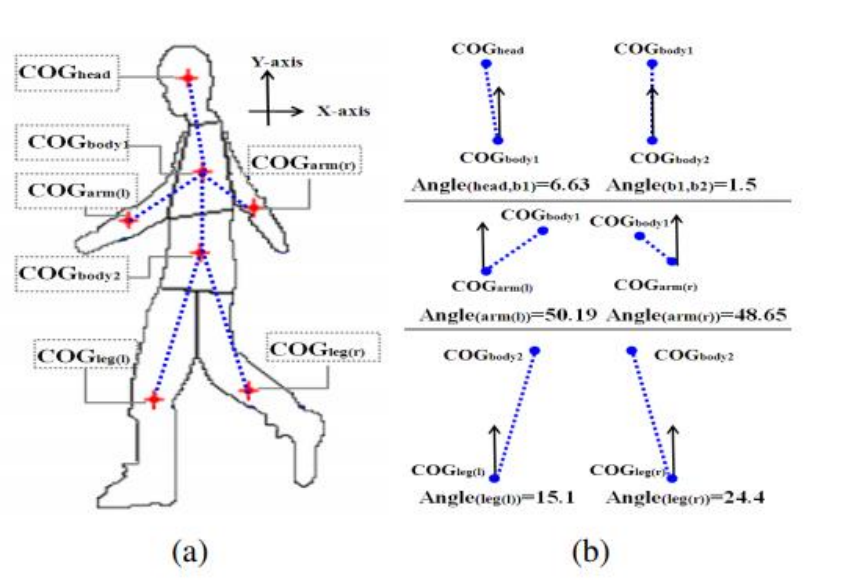
Developments in force plate
(detailed pressure map,
biomechanical analysis  etc.)



Bertec Co., Tekscan Co.

# FUTURE

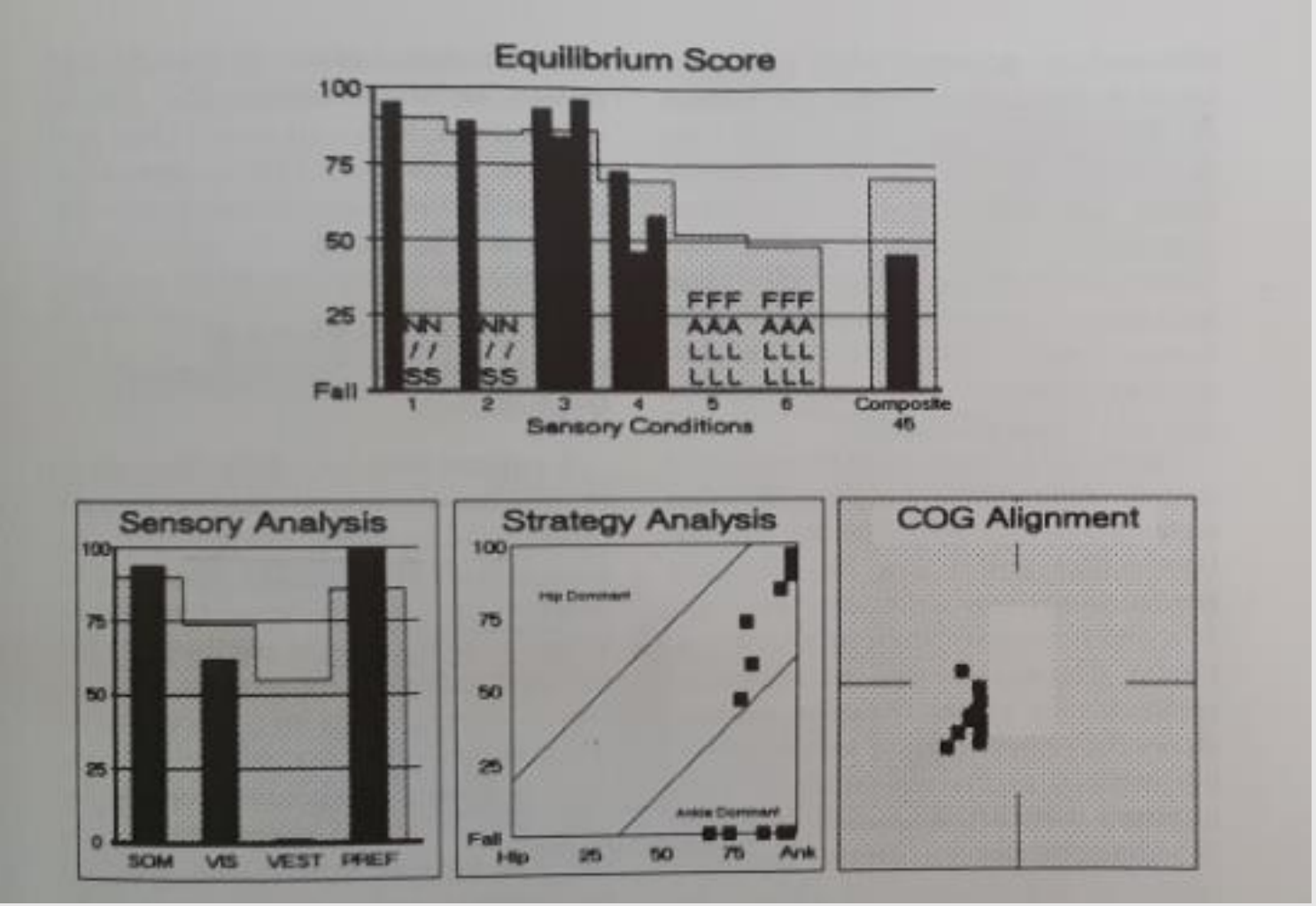
Wearable motion sensors or video capture for detecting trunk, head or arm movements-whole body movement analysis


Xsens Co. , Qualysis Co., Ying-Fang Tsao, Wen-Te Liu yand Ching-Te Chiu Human Gait Analysis by Body Segmentation and Center of Gravity

# CASE INTERPRETATIONS

Nashner LM. CDP: Clinical Applications. In (Eds.) Jacobson GP, Newman CW, Kartush JM. Handbook of Balance Function Testing.Mosby Year Book 1993.




35- yr.-old lady

Mild and intermittent disorientation and unsteadiness

Examination : Normal

Unilateral weakness

Equilibrium Scores

Sensory analysis: primarily vestibular dysfunction pattern + secondarily visual dysfunction

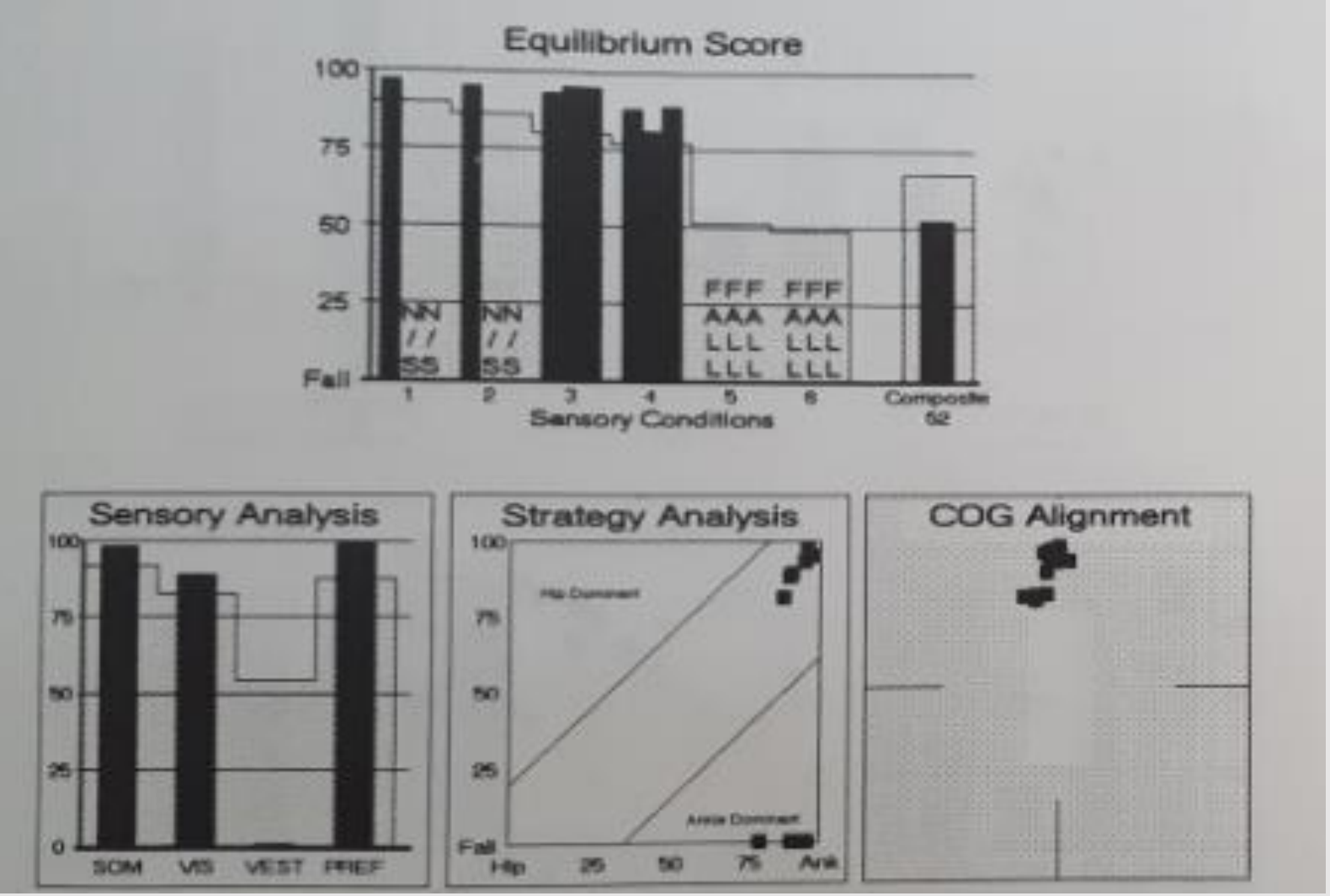
Strategy analysis: Abnormal reliance on ankle movement during large amplitude sway

COG alignment:

MCT: Normal

CDP is compatible with a typical poorly compensated peripheral vestibular loss

Nashner LM. CDP: Clinical Applications. In (Eds.) Jacobson GP, Newman CW, Kartush JM. Handbook of Balance Function Testing.Mosby Year Book 1993.

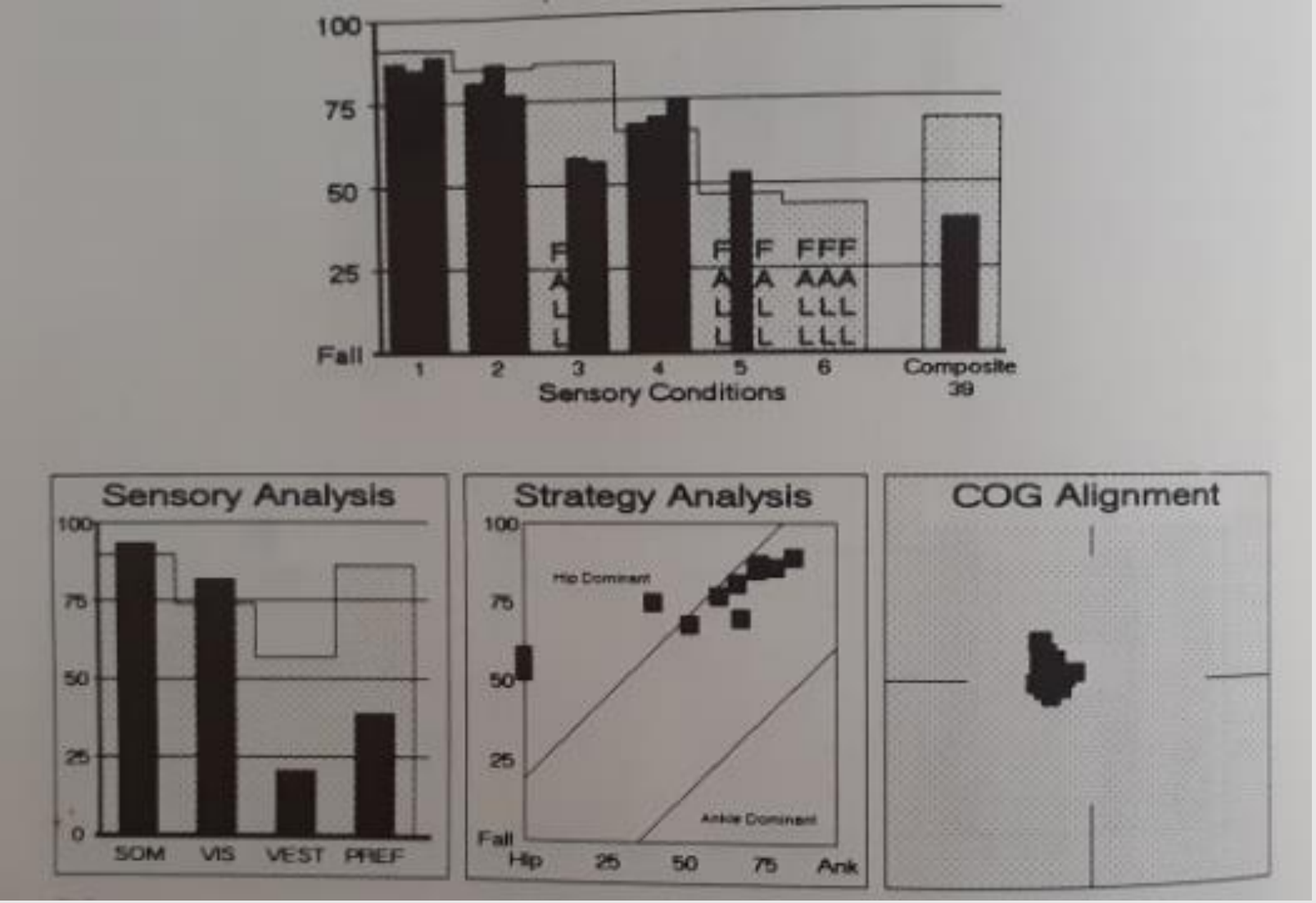



51- yr.-old man

Spontaneous episodic spells of ataxia and vertigo of mild intensity
Examination : Balance, gait, motor and sensory functions normal.
Equilibrium scores
Sensory analysis: vestibular dysfunction
Strategy analysis: abnormal dependence on ankle movements during large amplitude sway
COG
MCT: Normal
MR: Arnold Chiari malformation

CDP is compatible with vest.dysfunc. pattern affecting CNS pathways.

Nashner LM. CDP: Clinical Applications. In (Eds.) Jacobson GP, Newman CW, Kartush JM. Handbook of Balance Function Testing.Mosby Year Book 1993.

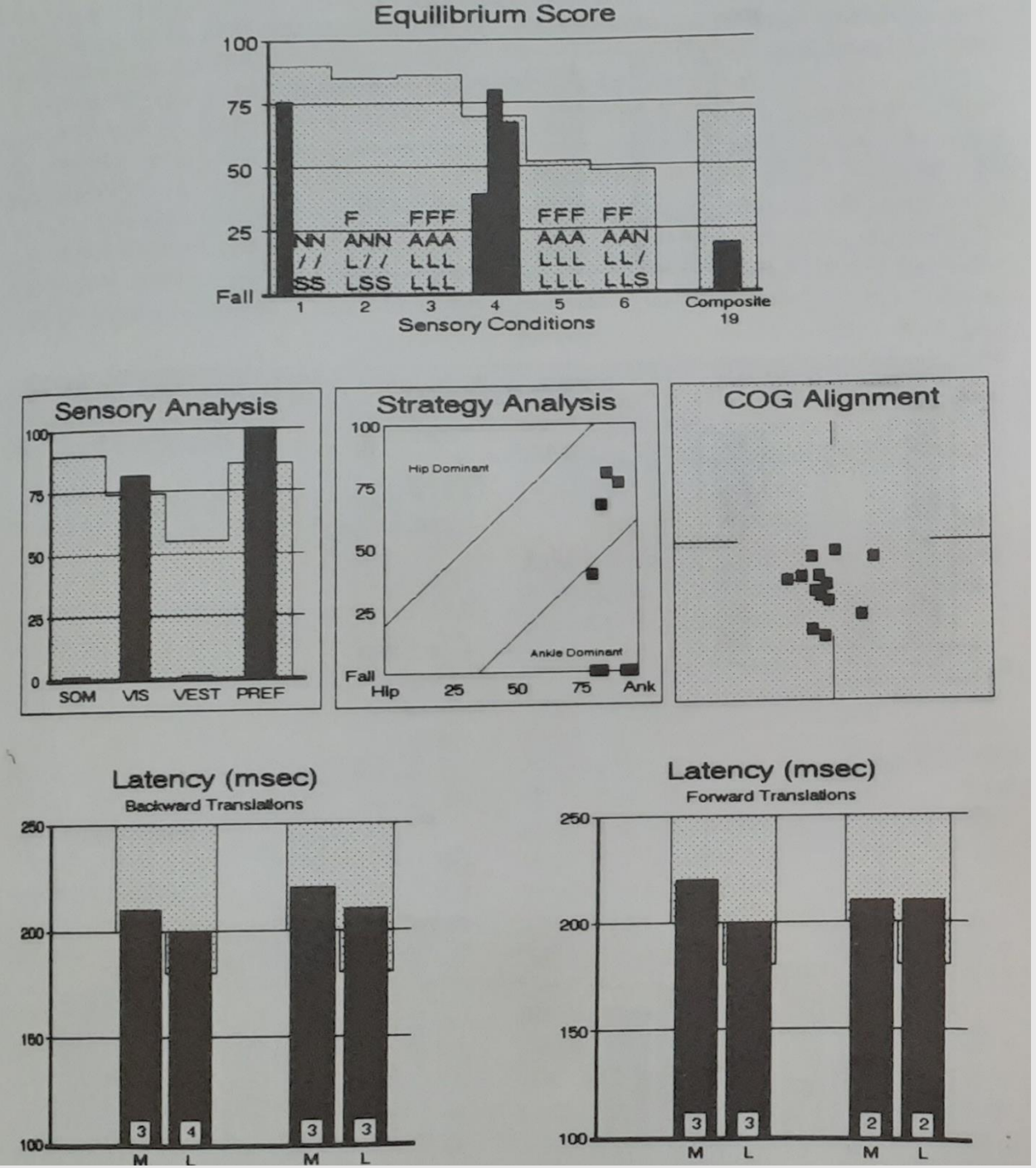



21- yr.-old man

Disorientation secondary to mild head trauma
Equilibrium scores in con 3,5,6
Sensory analysis: vest.dysfunction+ abnormal
visual preference
Strategy analysis
COG alignment: Normal
MCT : Normal
Examination: Normal
ENG: Normal
Rotary chair: mild phase abnormalities

Diagnosis: Post-traumatic vestibulopathy

Nashner LM. CDP: Clinical Applications. In (Eds.) Jacobson GP, Newman CW, Kartush JM. Handbook of Balance Function Testing.Mosby Year Book 1993.

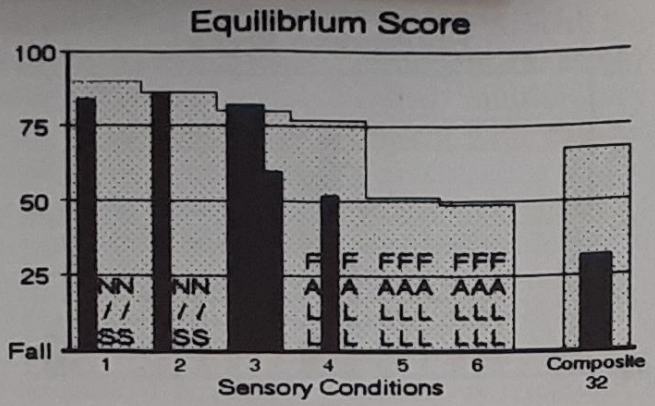


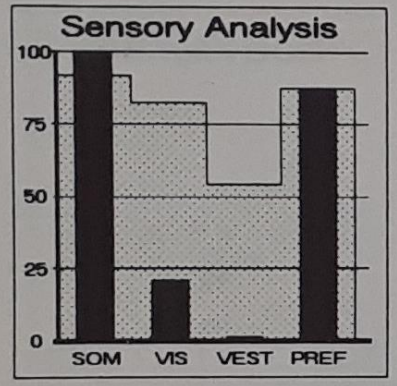

35- yr.-old man

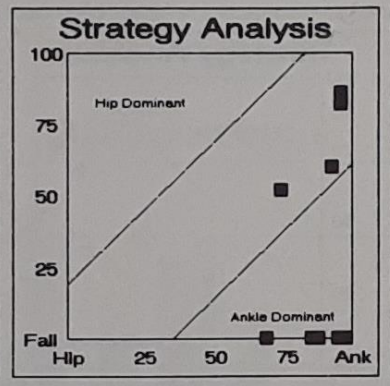
Dizziness and unsteadiness following accident- related head injury
Equilibrium score
Sensory analysis
Strategy analysis
COG aligment
UW
MCT: prolonged latency

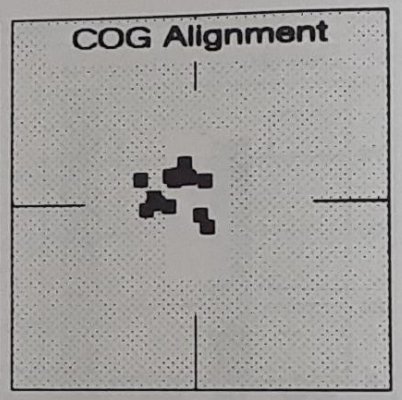
CDP shows the injury extending beyond the vest. system to include central motor control pathways (spinal cord, branstem and/or subcortical sensorimotor areas).

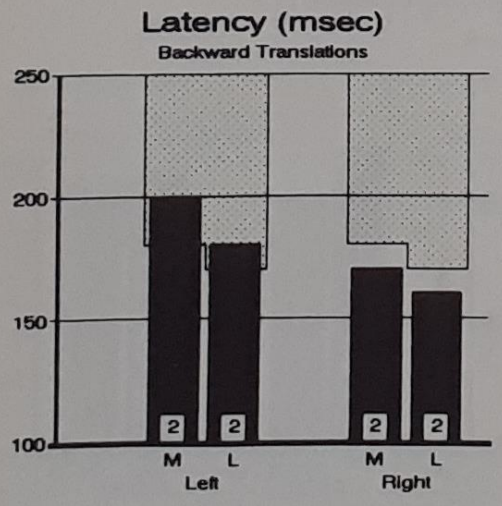
Nashner LM. CDP: Clinical Applications. In (Eds.) Jacobson GP, Newman CW, Kartush JM. Handbook of Balance Function Testing.Mosby Year Book 1993.

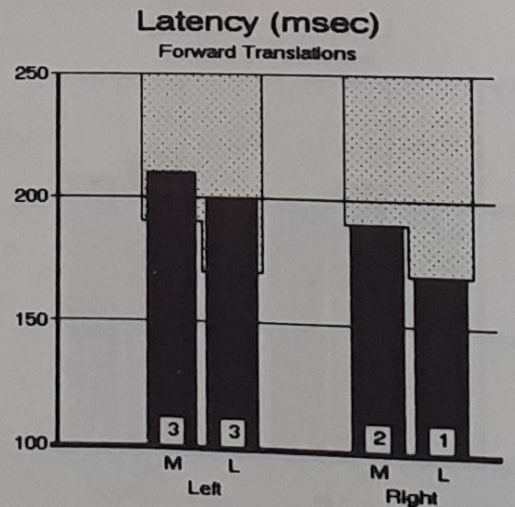


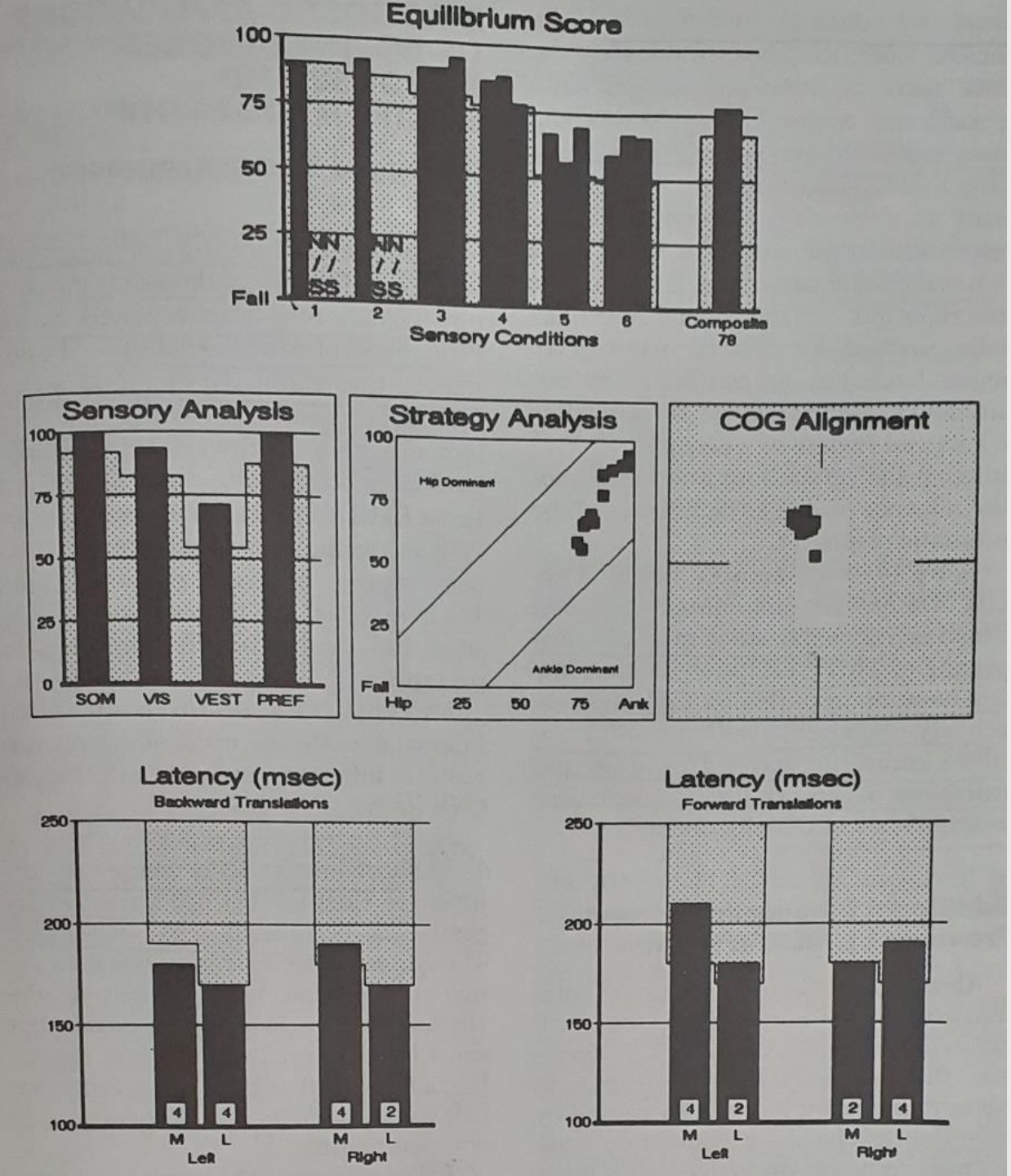




76- yr.-old lady

Unsteadiness for 2 weeks
Equibrium scores
Sensory analysis
MCT: prolonged latencies on the left side, borderline on the right.
ENG: Normal

Diagnosis:Stroke affecting localized central brain stem/subcortical areas

Nashner LM. CDP: Clinical Applications. In (Eds.) Jacobson GP, Newman CW, Kartush JM. Handbook of Balance Function Testing.Mosby Year Book 1993.

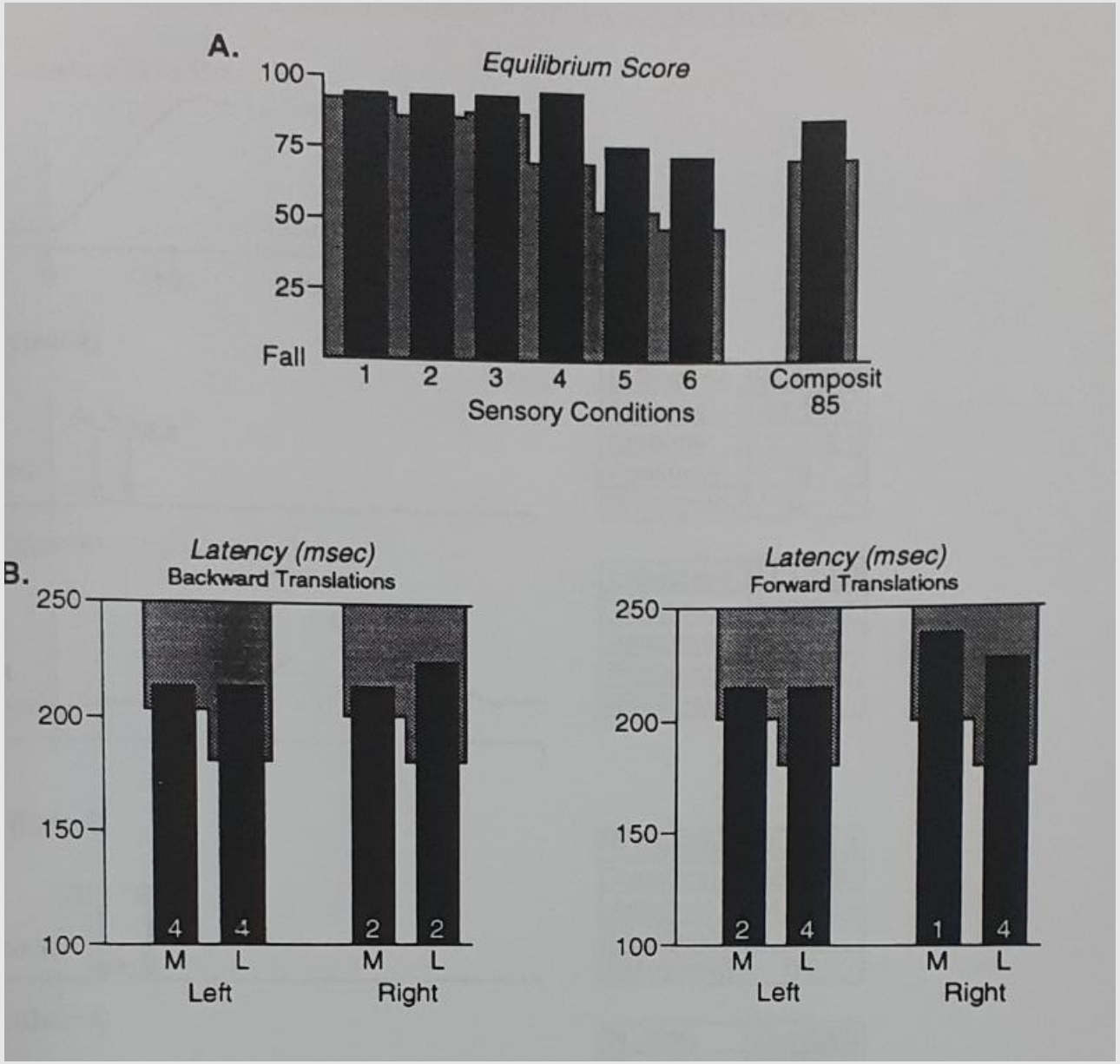



35- yr.- old lady

Chronic unsteadiness
Equilibrium scores
Sensory analysis
Strategy analysis
COG alignment
MCT: prolonged latencies indicating long loop motor pathway impaired

Diagnosis: Early stage of MS

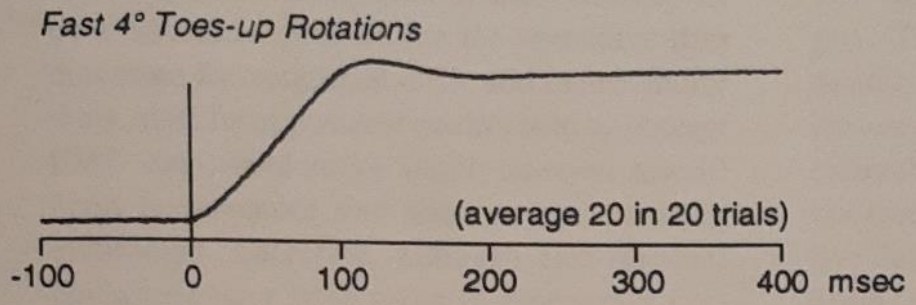
Nashner LM. CDP: Clinical Applications. In (Eds.) Jacobson GP, Newman CW, Kartush JM. Handbook of Balance Function Testing.Mosby Year Book 1993.

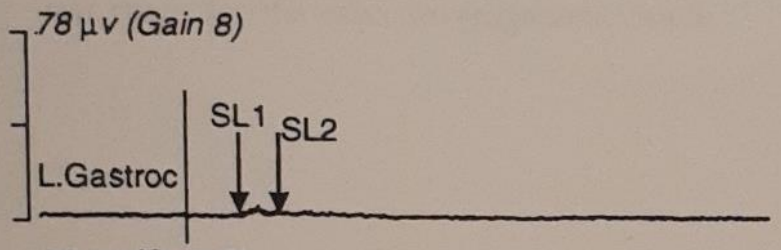



34-yr.-old lady

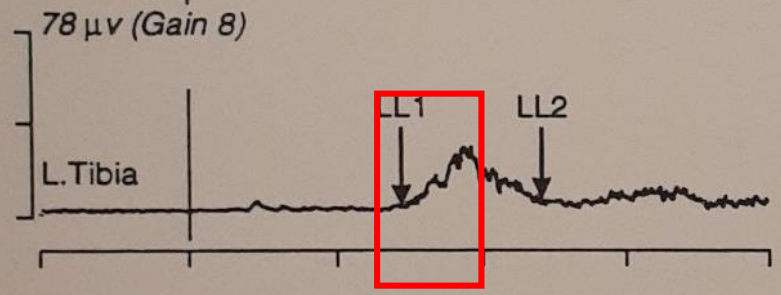
4 spontaneous vertigo spells in 10 years and
Left ear fullness
Vertigo spells last 2 days.
Milder residual symptoms slowly improves over 3 weeks.
ENG: 26% L UW, R beating positional nystagmus
Equilibrium scores
MCT

Telian SA, Sheppard NT. Practical management of the balance disorder patient. Singular Publishing Group, San Diego, 1996.

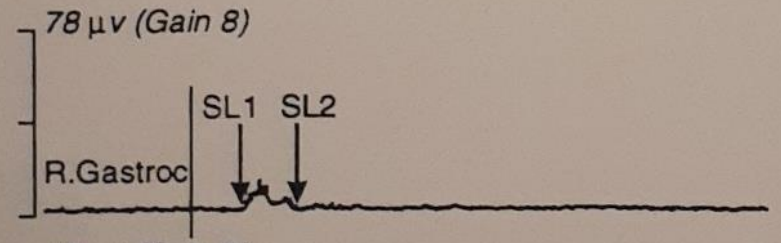



| L.Gastroc | SL1 | SL2 |
|---|---|---|
| Time(ms) | 39 | 55 |
| Amp(mv) | 2 | 2 |
| Peak(mv) | 6 | |
| IEMG(mvS) | 0.1 | |




| L.Gastroc | LL1 | LL2 |
|---|---|---|
| Time(ms) | 149 | 241 |
| Amp(mv) | 5 | 6 |
| Peak(mv) | 29 | |
| IEMG(mvS) | 1.3 | |




| R.Gastroc | SL1 | SL2 |
|---|---|---|
| Time(ms) | 38 | 69 |
| Amp(mv) | 4 | 2 |
| Peak(mv) | 15 | |
| IEMG(mvS) | 0.2 | |

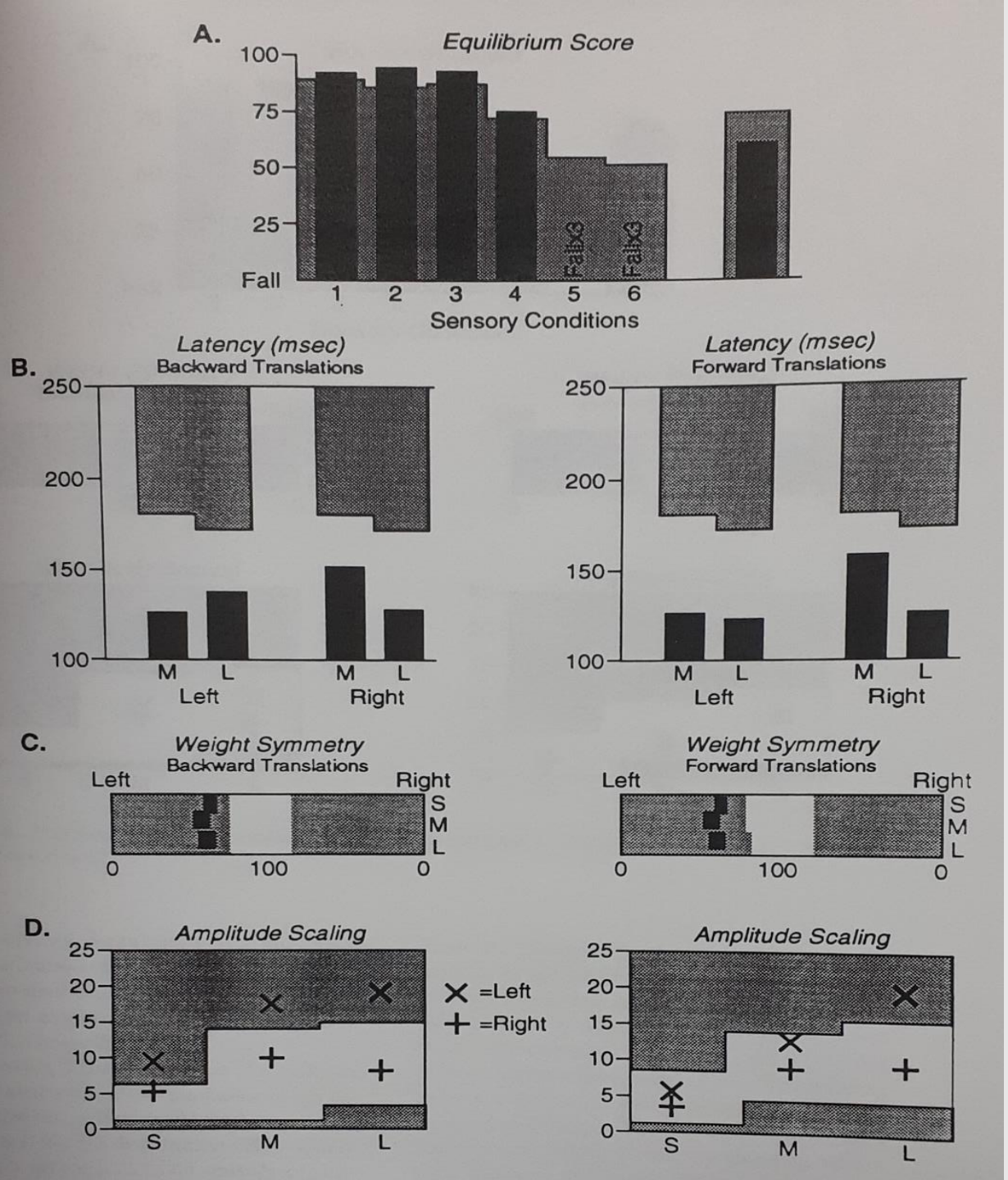

| R. Tibia | LL1 | LL2 |
|---|---|---|
| Time(ms) | 147 | 222 |
| Amp(mv) | 3 | 5 |
| Peak(mv) | 17 | |
| IEMG(mvS) | 0.7 | |

PER: prolonged LL1 for R and L tibialis anterior muscle

Diagnosis: MS

Telian SA, Sheppard NT. Practical management of the balance disorder patient.

Singular Publishing Group, San Diego, 1996.




47 -yr.-old man

Vertigo provoked by head movements, rare mild spells of vertigo lasting seconds

Pain and swelling in the left lower limb

L vestibular neurectomy for intractable MD

L transmastoid labyrinthectomy for continuing spells of vertigo and deteriorated HL

ENG: right beating positional nystagmus , L- UW

Equilibrium score

MCT

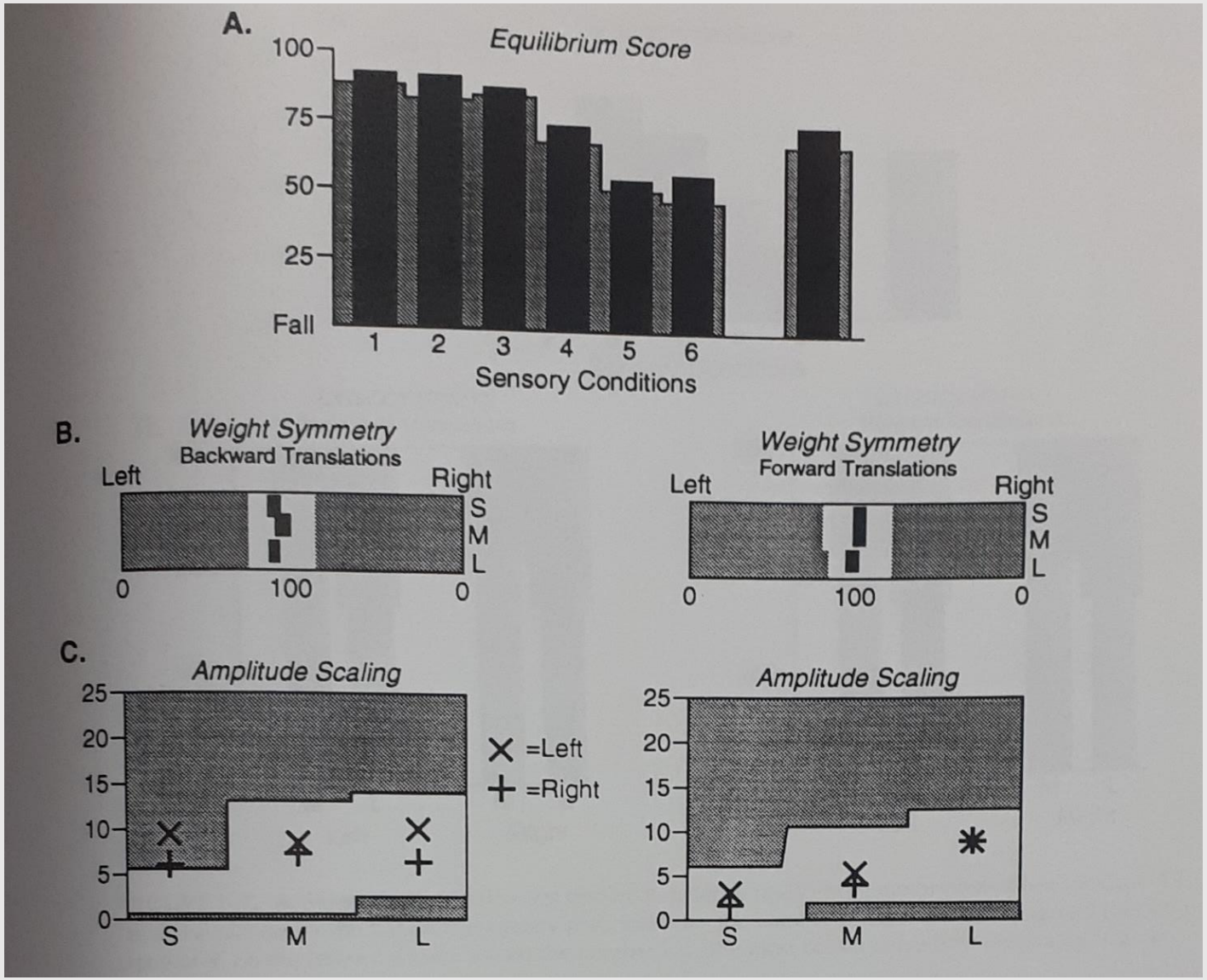
Weight symmetry

CDP is compatible with lack of compensation and maladaptive behaviour ( weight bearing abnormality)

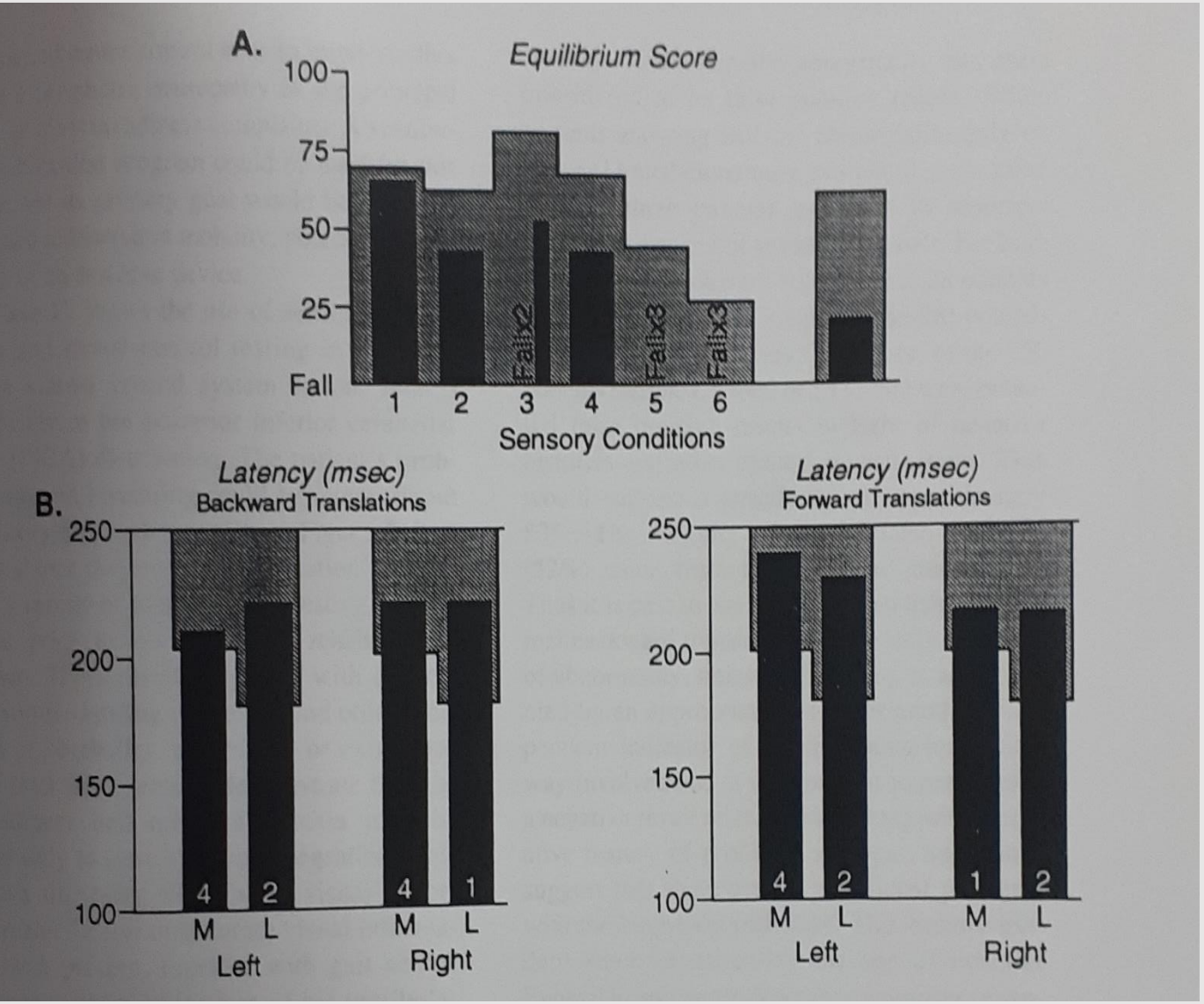
Vestibular rehab. program included balance and gait exercises focused on equal weight distribution.

Telian SA, Sheppard NT. Practical management of the balance disorder patient. Singular Publishing Group, San Diego, 1996.

# Posttherapy CDP




Telian SA, Sheppard NT. Practical management of the balance disorder patient. Singular Publishing Group, San Diego, 1996.

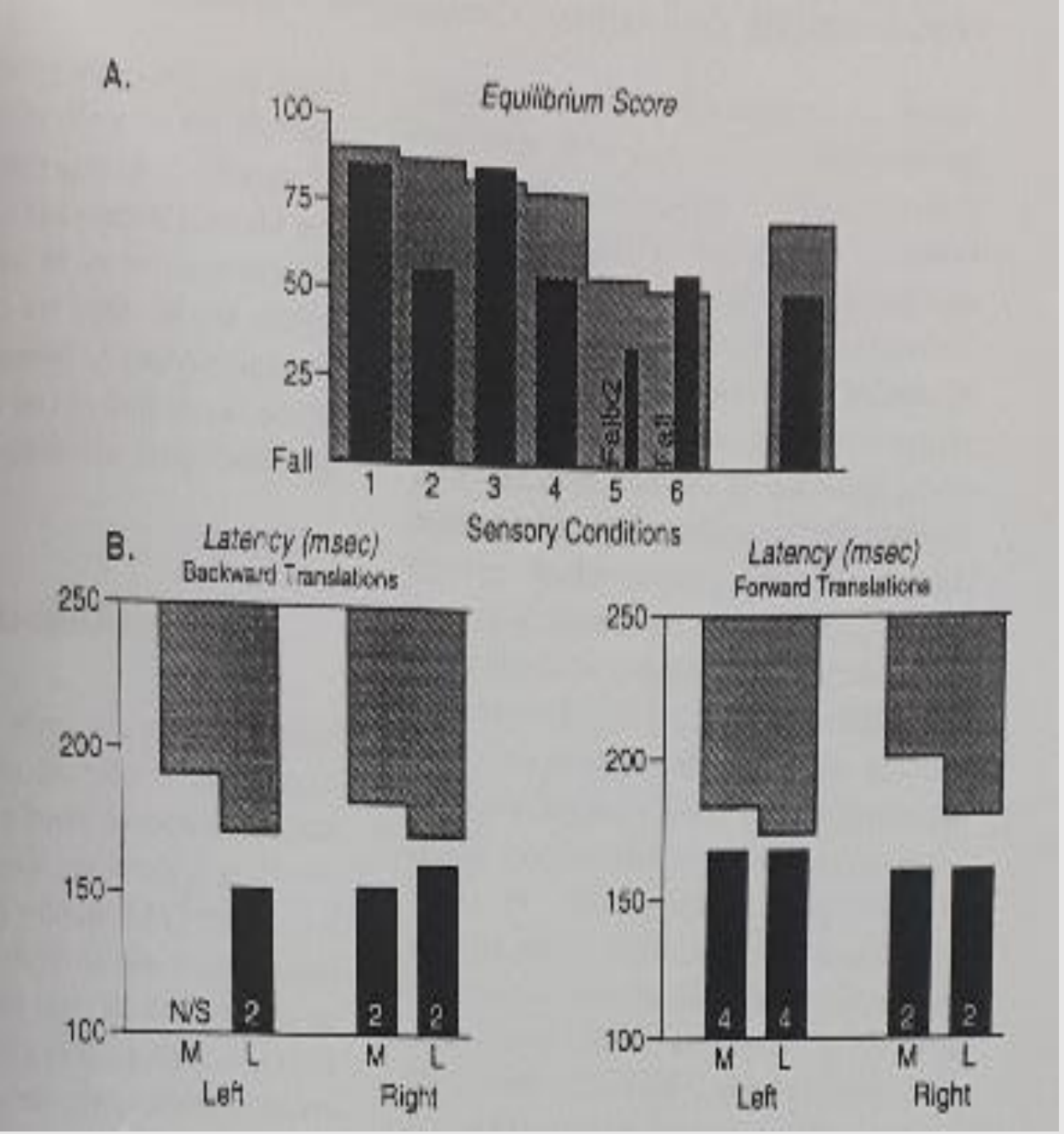



84-yr.-old man

Constant unsteadiness when standing and walking for a year
Symptoms not provoked by head movements
Edema in ankles
Auditory symptoms (-)
ENG: Normal
Equilibrium scores
MCT
Scaling and weight distribution are normal

CDP is compatible with an inability to use any combination
of sensory inputs due to severe peripheral neuropathy.

Telian SA, Sheppard NT. Practical management of the balance disorder patient. Singular Publishing Group, San Diego, 1996.




65-yr.- old man

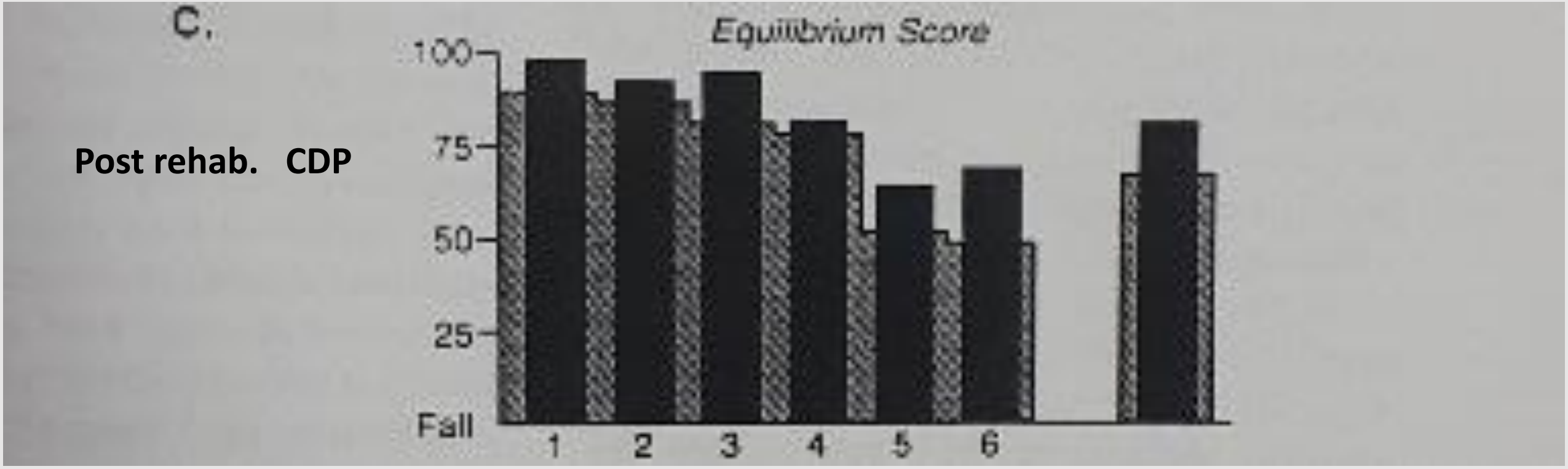
Sudden onset of disequilibrium and nausea following heart catheterization
Disequilibrium became unsteadiness. Pulling and pushing sensations lasting several seconds few times a week
Head movements increases his complaints.
Triple coronary artery bypass op. some years ago
Bilateral high freq. HL
ENG: L beating spon. and positional nystagmus 4-6 $^{0}$ /sec , DP 78% to the left, UW 14% in the right ear
Oculomotor findings support central lesion
MR: left lateral medullary infarct
Equilibrium score
MCT

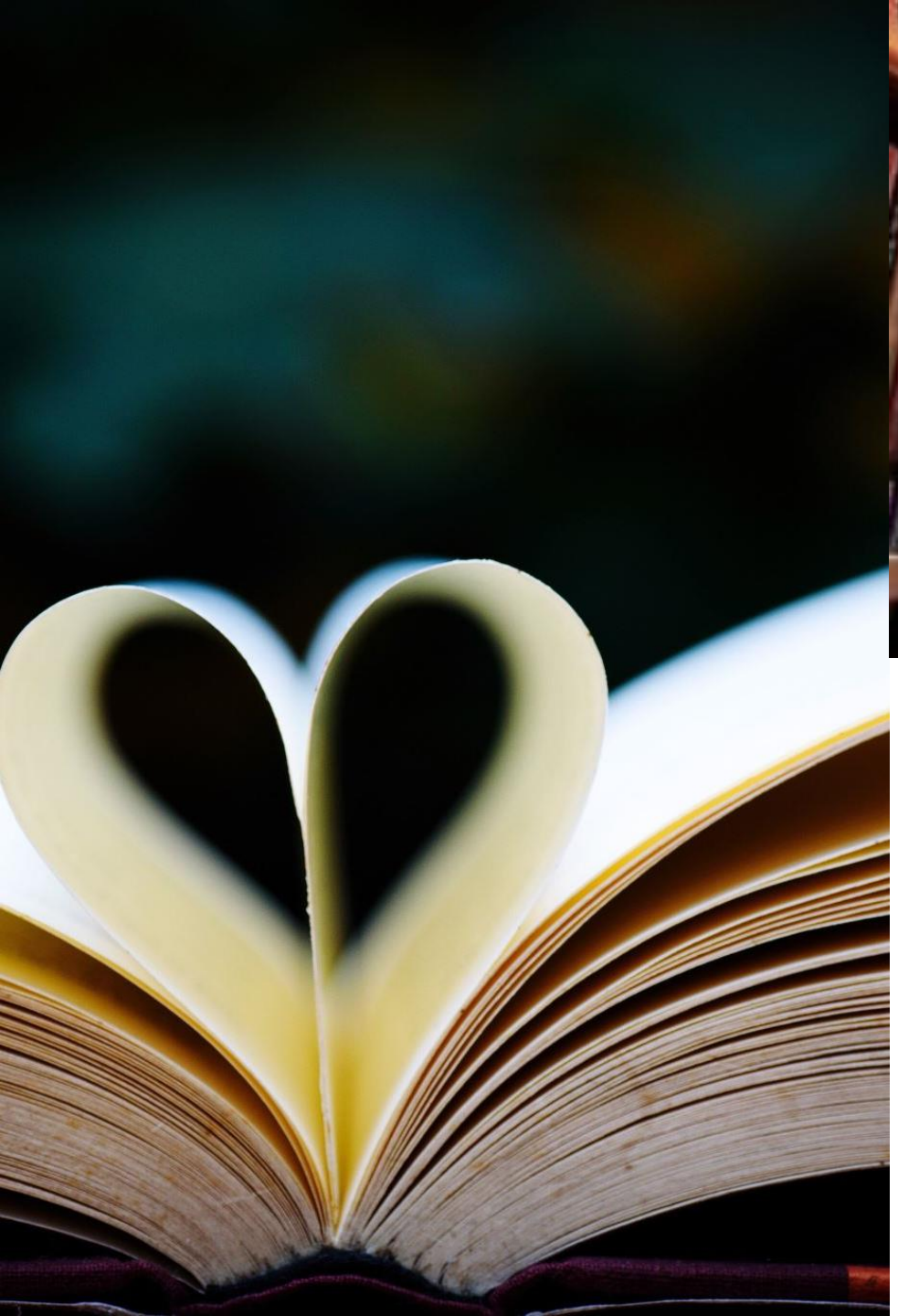
Telian SA, Sheppard NT. Practical management of the balance disorder patient. Singular Publishing Group, San Diego, 1996.

Gait instability could be originated from motor output or sensory input abnormality.

Clinical evaluations showing dysmetria and other indicator of cerebellar, pyramidal and extrapyramidal tract involvement demonstrate that unsteadiness and gait ataxia may be related only to sensory input integration.

**Post rehab. CDP**





# THE LITERATURE

# Rates of CDP Abnormalities

**TABLE 1.** *Computerized dynamic posturography abnormalities in peripheral vestibular disease*

| Percent | Study |
|---|---|
| 45% | Voorhees (26) |
| 79% | Hamid, et al. (27) |
| 65% | Keim (14) |
| 57% | Lipp and Longridge (9) |

**45% 79%**

**TABLE 2.** *Computerized dynamic posturography abnormalities in central nervous system disorders*

| Percent | Study |
|---|---|
| 72% | Voorhees (26) |
| 90% | Voorhees (13) |
| 74% | Hamid, et al.(27) |
| 95% | Keim (14) |

**72% 95%**

Dobie RA. Does computerized dynamic posturography help us care for our patients? Am J Otol 1997 Jan;18(1):108-12.

# Role of CDP in Perilymph Fistula

**Platform pressure test**

- 77 pts.  were clinically suggestive perilymph fistula cases
- 75 were CDP test positive
- 73 were surgically confirmed

Black FO. Otolaryngol HNS 1987;96:125-134.

# Meta-analysis of the Sensitivity and Specificity of Posturography

9 articles, 1477 pts,  13% BPPV  19% Meniere's disease  31% Other peripheral vestibular diseases
3.3% Central nervous system dis.  33.5% (498 pts)  Normal

| Dependent Variable | Mean (±SD) |
|---|---|
| Sensitivity, % | 51 (±23) |
| Specificity, % | 44 (±12) |
| Predictive value, % | |
| Normal | 40 (±19) |
| Abnormal | 54 (±23) |

Richard P. Di Fabio. Arch Otolaryngol Head Neck Surg. 1996;122:150-156

## Conclusion

- ❖Use of posturography combined with other tests of vestibular function is likely to increase the detection of vestibular deficits.
- ❖Posturography provides a significant supplement to the standard vestibular examination when the target population includes pts. with CNS deficits.
- ❖For pts. with peripheral diseases posturography adds less to the detection of deficits

Richard P. Di Fabio. Arch Otolaryngol Head Neck Surg. 1996;122:150-156

# Role of CDP in Differentiation between Bilateral and Unilateral Vestibular Loss

11 pts with bilateral and 101 pts with unilateral vestibular loss

In static conditions, only bilateral vestibular loss patients had abnormal values compared to controls.

In dynamic eyes-closed conditions, both bilateral and unilateral patients could be differentiated from controls.

Mbongo F, Patko T, Vidal PP, Vibert N, Tran Ba Huy P, de Waele C. Postural control in patients with unilateral vestibular lesions is more impaired in the roll than in the pitch plane: a static and dynamic posturography study. Audiol Neurootol. 2005;10(5):291-302.

# Differentiation between Bilateral Vestibular Loss and Cerebellar Atrophy

- Sway velocity and amplitude are increased in pts. with bilateral vestibular loss and cerebellar atrophy.
- None of the CDP parameter can reliably differentiate these two.

Baloh RW et al. 1998

## Conclusion

PPPD pts. showed more or less deficits in Vis, Ves and SS system and multi-modality integration.

In patients with PPPD, CDP may be useful for demonstrating specific patterns of functional impairment.

Söhsten E, Bittar RS, Staab JP. Posturographic profile of patients with persistent postural-perceptual dizziness on the sensory organization test. J Vestib Res. 2016; 2;26(3):319-26.

# CDP in Patients with Motion Sickness/Seasickness

20 subjects susceptible to seasickness

20 controls

- Seasickness group exhibited significantly less stability than controls in SOT condition ***5***
- Vestibular dysfunction pattern was noted in seasickness group

Results of the Sensory Organization Test, and Significance of Differences Between Groups, Using Logistic Regression.

| | Susceptibles (n = 20) | | Nonsusceptibles (n = 20) | | |
|---|---|---|---|---|---|
| Subtest | Abn (n)* | Mean ± SD | Abn (n)* | Mean ± SD | *P* Value |
| Condition 1 | 0 | 93.2 ± 1.4 | 0 | 94.3 ± 1.7 | 0.36 |
| Condition 2 | 1 | 91.8 ± 3.4 | 0 | 92.4 ± 2.7 | 0.10 |
| Condition 3 | 4 | 87.7 ± 6.9 | 0 | 92.3 ± 2.4 | 0.29 |
| Condition 4 | 8 | 77.4 ± 10.8 | 1 | 86.5 ± 7.8 | 0.96 |
| Condition 5 | 5 | 59.4 ± 12.1 | 0 | 81.5 ± 14.5 | 0.03 |
| Condition 6 | 5 | 55.4 ± 17.0 | 1 | 77.9 ± 19.7 | 0.81 |
| SOM | 1 | 0.99 ± 0.04 | 0 | 0.98 ± 0.03 | 0.08 |
| VIS | 4 | 0.83 ± 0.12 | 1 | 0.92 ± 0.08 | 0.74 |
| VEST | 6 | 0.64 ± 0.13 | 1 | 0.86 ± 0.15 | 0.006 |
| PREF | 5 | 0.95 ± 0.13 | 2 | 0.98 ± 0.09 | 0.34 |

Shahal B, Nachum Z, Spitzer O, Ben-David J, Duchman H, Podoshin L, Shupak A. Computerized dynamic posturography and seasickness susceptibility. Laryngoscope. 1999;109(12):1996-2000.

# CDP vs ENG
# Predicting Fall Risks in an Elderly Population:

35 pts. > 65 years

**26 pts**. **(78.8%)** had abnormal results on CDP

CDP:70.7% had abnormal results on LOS

70.7% showing abnormal scores on SOT

19 (57.8%) of pts. had abnormal scores for both SOT and LOS

6 (18.2%) had normal CDP

**20 pts. (60.6%)** showed ENG abnormalities (42.4% for oculomotor test, 28.6% for positional test, 13.6% for caloric test)

**18 pts. (54.5%)** had abnormal results for CDP and ENG

**Only 3 pts. (9.1%)** had normal findings for CDP and ENG

Girardi M, Konrad HR, Amin M, Hughes LF. Predicting fall risks in an elderly population: computer dynamic posturography versus electronystagmography test results. Laryngoscope. 2001 ;111(9):1528-32

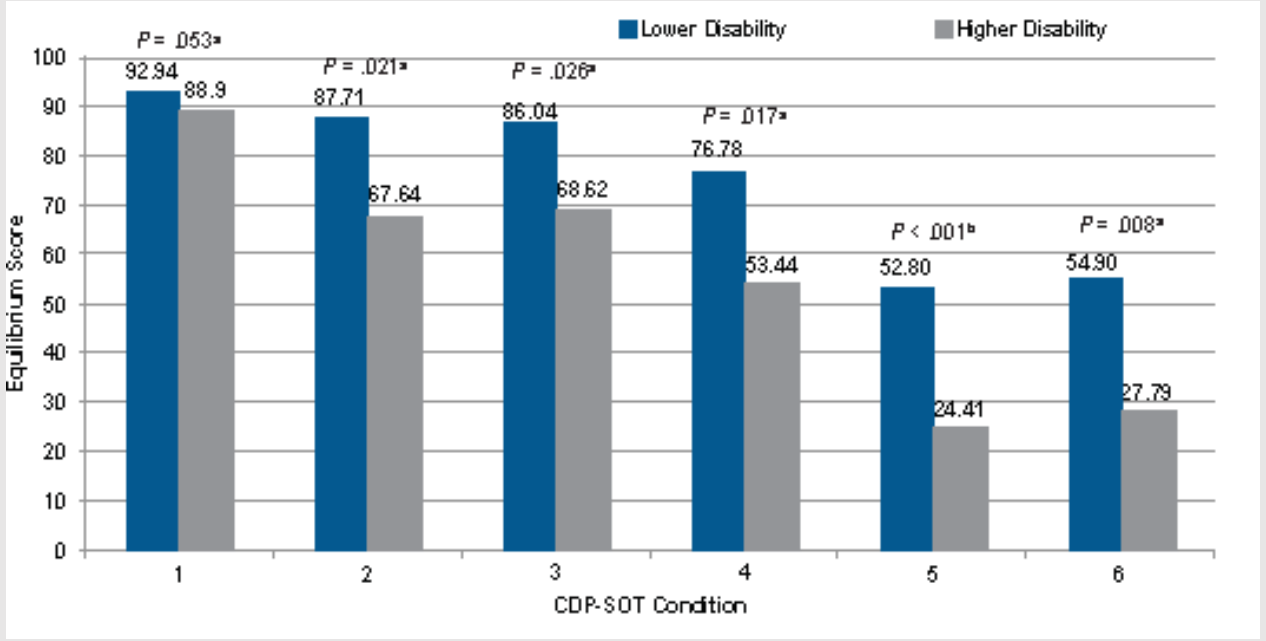
# SOT in Patients with MS

30 patients

Composite scores were significantly greater in lower-disability group vs higher-disability group

The CDP-SOT is a reliable measure of balance. It accurately differentiates disability status in people with MS.

The results support clinical application of SOT as a reliable and valid measure of disease-related progression of impaired balance.




Hebert JR, Manago MM. Reliability and Validity of the Computerized Dynamic Posturography Sensory Organization Test in People with Multiple Sclerosis. Int J MS Care. 2017; 19(3):151-157.

# CDP Findings in Meniere's Disease

63 pts. with Meniere's disease

SOT results were analysed according to the pattern offered by the device and through the application of the Cevette formulae

## Calculation of the Cevette formulae

**Normal**: −238.14+(2.24*Eq SOT1)+(1.45*Eq SOT2)+(1.74*Eq SOT4)−(0.13*Eq SOT5)

**Aphysiological**: −158.2+(1.94*Eq SOT1)+(1.09*Eq SOT2)+(1.37*Eq SOT4)−(0.15*Eq SOT5)

**Vestibular** : −251.21+(2.31*Eq SOT1)+(1.54*Eq SOT2)+(1.89*Eq SOT4)−(0.58*Eq SOT5)

Eq: result in the study condition

Doménech-Vadillo E, Montes-Jovellar L, Rey-Martínez J, Pérez-Fernández N. Normal and vestibular patterns in dynamic posturography in patients with Meniere's disease. Acta Otorrinolaringol Esp. 2010;61(1):34-40.

In 63 pts. the pattern obtained was normal or vestibular dysfunction.

In 41, the patterns obtained through both analysis systems were in agreement.

In 22, the systems were not consistent . The analysis of pts. using the Cevette formulae offered a higher capacity for clinical discrimination, but was not sensitive to the bias introduced by age.

Cevette formulae in combined with the classification offered by the device managed to differentiate two populations (normal and vestibular) with a very good audio-vestibular correlation.

Doménech-Vadillo E, Montes-Jovellar L, Rey-Martínez J, Pérez-Fernández N. Normal and vestibular patterns in dynamic posturography in patients with Meniere's disease. Acta Otorrinolaringol Esp. 2010;61(1):34-40.

# Efficacy of CDP and ENG in Detecting Balance Impairment Associated with Cerebral White Matter Changes

80 pts. with and 57 pts. w/o white matter changes

CDP (SOT, MCT) vs ENG (oculomotor, positional and caloric tests)

| | No WMCs n = 57 | WMCs n = 80 | *p* |
|---|---|---|---|
| CDP | %Abnormal | %Abnormal | |
| Somatosensory | 4% | 15% | 0.025 |
| Visual | 25% | 48% | 0.008 |
| Vestibular | 30% | 53% | 0.005 |
| Preference | 5% | 18% | 0.063 |
| Strategy | 11% | 25% | 0.027 |
| COG | 23% | 50% | 0.001 |
| Overall SOT | 44% | 89% | <0.001 |
| MCT composite | 2% | 29% | <0.001 |
| Overall CDP | **44%** | **93%** | **<0.001** |

| | No WMCs n = 57 | WMCs n = 80 | *p* |
|---|---|---|---|
| ENG | %Abnormal | %Abnormal | |
| Positional | 50% | 63% | 0.120 |
| Saccade | 32% | 47% | 0.098 |
| Pursuit | 11% | 11% | 0.846 |
| Optiokinetic | 29% | 52% | 0.008 |
| Caloric | 33% | 29% | 0.505 |
| Overall ENG | **81%** | **86%** | **0.435** |

Urban MJ, Sataloff RT. Efficacy of CDP and ENG in Detecting Balance Impairment Associated With Cerebral White Matter Changes. Otol Neurotol. 2016;37(9):1457-61

## Conclusion

The pts. with cerebral white matter changes are significantly more likely to have an abnormal balance result as detected by CDP, than by ENG.

CDP may be a better study to identify and document pts. who have balance dysfunction associated with this central finding.

Urban MJ, Sataloff RT. Efficacy of CDP and ENG in Detecting Balance Impairment Associated With Cerebral White Matter Changes. Otol Neurotol. 2016;37(9):1457-61

# Aphysiologic Performance on CDP

The aphysiologic group perform significantly better in conditions 5 and 6, yet significantly poorer in conditions 1 through 4.

Pts. in the aphysiologic group tend to show greater inter-trial variability compared with patients in both normal and vestibular system dysfunction groups.

Cevette MJ, Puetz B, Marion MS, Wertz ML, Muenter MD. Aphysiologic performance on dynamic posturography. Otolaryngol Head Neck Surg. 1995;112(6):676-88

# Aphysiologic Response to CDP

1.**Substandard performance on SOT 1.** Score equals number of points below norm for the best trial of SOT 1. Enter zero if above norm.

2.Lower scores on SOT 1 and 2, higher scores on SOT 5 and 6. Using best individual trials,

score equals [(Score 1 - Norm 1) + (Score 2 - Norm2)]

-

[(Score 5 - Norms) + (Score 6 - Norm6)].

3.Repetitive large-amplitude AP sway without falling. Score equals the average number of AP sways that exceed 7.5 degrees for each trial of SOT 4, 5 and 6 without a fall.

4.Excessive lateral sway without falling. Score equals the average number of lateral sways that exceed ±2.5 degrees from the patient's COG for each trial of SOT 4, 5 and 6 without a fall.

5.Excessive variability on SOT 1 and 2. Score equals average of standard deviations for all trials of SOT 1 and 2.

6. **Exaggerated motor responses to small platform translations.** Score equals average number of degrees of sway across trials for small forward and small backward displacements.

7. **Inconsistent motor responses to small and large, forward and backward platform translations.** Score equals number of tests with at least two of three "concordant" trials per test. Maximum score equals 4.

Goebel JA, Sataloff RT, Hanson JM, Nashner LM, Hirshout DS, Sokolow CC. Posturographic evidence of nonorganic sway patterns in normal subjects, patients, and suspected malingerers. Otolaryngol Head Neck Surg. 1997;117(4):293-302

**Table 1.** Percentage of subjects with positive criteria for aphysiologic sway

| Criterion | Cutoff | Normals | Patients | Malingerers | Sensitivity | Specificity |
|---|---|---|---|---|---|---|
| 1 | 0 | 0% | 5% | 72% | 72% | 96% |
| 2 | — | — | — | — | — | — |
| 3 | 0 | 4% | 25% | 31% | 31% | 80% |
| 4 | 0 | 18% | 75% | 57% | 57% | 40% |
| 5 | — | — | — | — | — | — |
| 6 | 2* | 2% | 5% | 32% | 32% | 95% |
| 7 | 4 | 1% | 7% | 72% | 72% | 95% |

Sensitivity and specificity calculations are noted for each criterion separately.

**Table 2.** Percentage of subjects with multiple positive criteria for aphysiologic sway

| Combination | Normals | Patients | Malingerers | Sensitivity | Specificity |
|---|---|---|---|---|---|
| 1 & 6 | 0% | 1% | 28% | 28% | 99% |
| 1 & 7* | 0% | 0% | 57% | 57% | 100% |
| 6 & 7 | 1% | 1% | 28% | 28% | 99% |
| 1 & 6 & 7 | 0% | 0% | 25% | 25% | 100% |
| 1 or 6 | 2% | 9% | 76% | 76% | 93% |
| 1 or 7 | 1% | 12% | 88% | 88% | 91% |
| 6 or 7 | 2% | 12% | 76% | 76% | 91% |
| 1 or 6 or 7* | 2% | 15% | 89% | 89% | 88% |
| (1 & 6) or 7 | 23% | 8% | 75% | 75% | 94% |
| 1 & (6 or 7) | 0% | 1% | 60% | 60% | 99% |
| 1 or (6 & 7)* | 1% | 6% | 75% | 75% | 96% |
| (1 or 6) & 7 | 1% | 1% | 60% | 60% | 99% |
| (1 or 7) & 6 | 1% | 2% | 31% | 31% | 98% |
| (1 & 7) or 6 | 2% | 5% | 64% | 64% | 95% |

Sensitivity and specificity calculations are shown for all combinations of criteria 1, 6, and 7.
*Optimal combinations (see Results section).

Goebel JA, Sataloff RT, Hanson JM, Nashner LM, Hirshout DS, Sokolow CC. Posturographic evidence of nonorganic sway patterns in normal subjects, patients, and suspected malingerers. Otolaryngol Head Neck Surg. 1997;117(4):293-302

# A New Set of Criteria for Evaluating Malingering in Work-Related Vestibular Injury

**TABLE 2.** *Nine criteria for malingering*[a]

| Criterion | Description |
|---|---|
| 1 | Better performance on Conditions 1 and 2 when unaware |
| 2 | Conditions 1 and 2 markedly below normal |
| 3 | Conditions 5 and 6 relatively better than Conditions 1 and 2 |
| 4 | Circular sway (i.e., lateral and anteroposterior together) without any falls |
| 5 | High intertrial variability on all SOT trials |
| 6 | Repeated suspiciously consistent sway patterns throughout SOT trials |
| 7 | Exaggerated MCT responses |
| 8 | Inconsistent MCT responses |
| 9 | "Gut feeling" (i.e., clinical judgment) |

Score <3 does not indicate aphysiologic behaviour
score 3 or 4 is suspicious for aphysiologic behavior
Score 5 or > represents aphysiologic behavior

Mallinson AI, Longridge NS. A new set of criteria for evaluating malingering in work-related vestibular injury. Otol Neurotol. 2005;26(4):686-90.

# Fields of Interest and Targeted Population

**Types of Balance Problems**: Instability, Visual instability, Dizziness

# Targeted Population and Disease Groups

Rehab. of amputee

Aviation medicine

CVA related balance /mobility problems

Chemical toxicity, ototoxicity

Chronic mobility/movement disorders

Falll risk identification and management

Head injury/concussion

Neuro degenerative dis.

Orthopedic  injuries

Pediatric and neurologic development

Spinal cord injury

Sports medicine

Vestibular disorders

Worker's compensation and medical legal issues

NeuroCom Intnl.Inc. Booklet, 2003

# CONDITIONS AFFECTING BALANCE DISORDERED-PATIENT MANAGEMENT

- Planning a course of postural rehab and monitoring response to the program in pts with vest. hypofunc and CNS dis.
- Determination of a need for CSF drainage with LP or shunting in pts with gait disturbance or dysequilibrium due to abnormal CSF pressure
- Documentation of postural responses in malingering persons (poorer performance in SOT 1 and 2 than SOT 5 and 6) or on the condition of exaggeration of disability for compensation or conversion disorder
- Diagnosing visual vertigo

Minor LB. Invited Comment. Utility of posturography in management of selected conditions that cause dizziness. Am J Otol. 1997 Jan;18(1):113-124.

# Answers Provided by CDP

1) Can the subject use vestibular info for postural control ?

2) Can the vestibular deficient patient use visual and support surface info for postural control?

3) Whether reflex latencies and strength are normal? Are postural control mechanisms in CNS normal, if not, which system is impaired, 3 sensory, motor or all?

4) Prediction who is likely or not likely to recover normal postural control after an ablative intervention.

5) An astronaut study showed that severity of postflight ataxia correlated with preflight SOT composites score.

Black FO. Invited Comment. Utility of posturography in management of selected conditions that cause dizziness. Am J Otol. 1997 Jan;18(1):113-124.
Cass SP, Kartush JM, Graham MD. Clinical assessment of postural stability following vestibular nerve section. Laryngoscope. 1991 Oct;101(10):1056-9.

# Conditions Requiring CDP Test

- Chronic dysequilibrium with unknown cause
- Chronic imbalance from central vestibular dysfunction
- Persistent dizziness or vertigo despite treatment
- Measuring baseline vestibular function prior to aggressive treatment, ablation. Pts with persistent dysequilibrium (abnormal CDP) may not compensate post ablation even if preoperative VOR is compensated. The issue here is the otolith function that is partially tested in CDP.
- Monitoring treatment outcome especially after ablation. CDP is the only available test to document status, prognosis and rehab outcome of pts with bilateral vestibular hypofunction.
- Identification of aphysiologic sway pattern and medical legal issues
- Determining of fall risk
- Identification of rehabilitative pattern that is needed, monitoring progress and outcome
- Selection of candidate worker who has to work in risky fields

Hamid MA. Invited Comment . Utility of posturography in management of selected conditions that cause dizziness. Am J Otol. 1997 Jan;18(1):113-124.

ANSWER: IF YOU ARE DEALING WITH THESE KINDS OF PATIENTS AND WORKING IN MENTIONED FIELDS, YOU SHOUD HAVE A CDP EQUIPMENT.

GOOD PLANNING WOULD BE REQUIRED FOR PURCHASING SUCH AN EXPENSIVE EQUIPMENT.

THIS PLANNING IS BASED ON SPECIFIC NECESSITIES (AVIATION ETC)

AND SIZE OF POPULATION TO BE SERVED.

Thank you for your attention and comments

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