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Computerized Dynamic Posturography
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Disclosures

- The opinions or assertions contained herein are the private views of the author and are not to be construed as official or reflecting the views of the University of Pittsburgh, United States Army, or Department of Defense.
Agenda

- Introduction
- Equipment, Patient Setup, and Testing Procedures
- Sensory Organization Test (SOT)
- Motor Control Test (MCT)
- Adaptation Test (ADT)
- Analysis
- Clinical Utility


Computerized Dynamic Posturography (CDP) - What is it?

- “a unique assessment technique used to objectively quantify and differentiate among the wide variety of possible sensory, motor, and central adaptive impairments to balance control” (NeuroCom, 2015)

- Can identify impairments in systems that contribute to balance
- Cannot diagnose pathology
History of CDP

- National Institutes of Health
- National Aeronautics and Space Administration

- 1982: Clinical tool described by Nashner et al
- 1986: EquiTest system introduced by NeuroCom International, Inc.
- Other systems: Balance System, Balance Quest, Modified-Clinical Test of Sensory Interaction in Balance, etc.

International Classification of Functioning, Disability, and Health

Health condition (disorder or disease)

Body Functions & Structure ➔ Activity ➔ Participation

Environmental Factors Personal Factors

Contextual factors (http://latrobe.libguides.com/who_icf)
CDP - Is it useful?

**Strengths**
1. Quantifies balance
2. Measures impairment (not pathology)
3. Good reliability
4. Operator bias during testing is limited
5. Patient may ‘cheat,’ but this is identifiable

**Weaknesses**
1. Constrained by manufacturer’s paradigms
2. Relationship of results to patient function is not well established
3. Is not a test of the vestibular system
4. The testing system must be purchased

(Herdman, 2010)

CDP - What’s the purpose?

- Goals of force plate measurement of balance:
  - Identify impairment(s) - the functional expression of pathology
  - Identify the patient’s strategy for maintaining balance
  - Determine if the patient is fully compensated (we would expect normal test results)
  - Provide guidance for treatment
  - Evaluate treatment effectiveness

(Herdman, 2010)
Balance

- Vestibular input
- Visual input
- Somatosensory input
- Central integration
- Neuromuscular output

Equipment

- Dual force plate support
  - Translate (horizontal)
  - Rotate (pitch)
- Moveable surround
- Safety harness
- Computer

http://www.frontiersin.org/files/Articles/72622/fnint-07-00091-HTML/image_m/fnint-07-00091-g001.jpg
Patient Setup

Safety harness is secured
Patient’s feet are aligned

Main Menu Screen for NeuroCom EquiTest
Selecting “Clinical Module” will allow the Audiologist to perform the SOT, MCT, and ADT as well as other tests
Clinical Module Screen for NeuroCom EquiTest

Selecting “New Patient File” will allow the Audiologist to add a new patient for testing, or, a previous patient can be selected from a list above [not shown to protect patient privacy].

New Patient File Screen for NeuroCom EquiTest

The Audiologist can enter the patient’s demographic information here, as well as an ID, referral source, operator (person administering the testing), diagnosis, and any other comments.

Height and Date of Birth are important for calibrating testing and comparing the patient to age-matched normative data.
Main Menu (for Current Patient) Screen for NeuroCom EquiTest
Selecting “Assessment” will allow the Audiologist to perform the SOT, MCT, and ADT as well as other tests or training (used for treatment)

Assessment Menu Screen for NeuroCom EquiTest
Selecting “Sensory Organization Test,” “Motor Control Test,” and “Adaptation Test” will allow the Audiologist to perform these tests
Patient Positioning Screens for NeuroCom EquiTest
The Audiologist is instructed where to place the patient’s feet based on the height information entered earlier.
Position the patient in order of: medial malleolus alignment, lateral calcaneus alignment, and splay.

Sensory Organization Test (SOT)

- Patient’s use of vestibular, visual, and somatosensory inputs in controlling balance
- During testing, visual and somatosensory input is altered through “sway referencing” of the surround or support surface
- Center of Pressure data is used to calculate movement of the Center of Mass
**SOT: Six Testing Conditions**

1. ![Testing Condition 1](image1)
2. ![Testing Condition 2](image2)
3. ![Testing Condition 3](image3)
4. ![Testing Condition 4](image4)
5. ![Testing Condition 5](image5)
6. ![Testing Condition 6](image6)

Sensory Organization Test (NeuroCom, 2015)

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**SOT - What are the limits of stability?**

- **Limits of stability**
  - 12.5° anterior-posterior (8° anterior, 4.5° posterior)
  - 16° laterally (8° left, 8° right)
- **Equilibrium Score** - amount patient sways is compared to 12.5° and converted to a score from 0 to 100
  - 0 = Fall
  - 100 = Perfect score (no anterior-posterior sway)
  - Shaded areas are scores for 95% of normal subjects

(Herdman, 2010)
SOT Comprehensive Report

- **Equilibrium Score** - quantifies the amount of postural sway (movement of the center of pressure)
  - Composite Equilibrium Score - weighted average of all scores; compared to age-matched norms
    - MCID 8 points (Wrisley, 2007)
    - <38 points increased risk of falls (Whitney, 2006)
- **Sensory Analysis** - attempts to quantify which sensory system is impaired
  - Somatosensory (SOM) - ratio score of SOT2 to SOT1
  - Visual (VIS) - ratio score of SOT4 to SOT1
  - Vestibular (VEST) - ratio score of SOT5 to SOT1
  - Preference (PREF) - ratio score of SOT3+6 to SOT2+5; how reliant a patient is on visual input, even when the visual input is incorrect

SOT Comprehensive Report

- **Strategy Analysis** - depicts the use of ankle and hip strategies to maintain balance
- **COG Alignment** - depicts the patient’s center of pressure on the force plate at the start of the trials

- For SOT to be “normal” the composite score *must* be normal
- If there are one or more abnormal SOT trials and the composite score is normal, then the interpretation is a normal test
Normal SOT Comprehensive Report

Abnormal SOT Comprehensive Report

(NeuroCom, 2015)
Example Case: SOT

- This is the comprehensive score report for a patient with a normal SOT
  - The patient is slightly more reliant on a hip strategy than an ankle strategy
  - The patient’s Center of Gravity is aligned slightly anterior

Example Case: SOT

- This is the raw data for a patient with a normal SOT
  - No regular periodicity of sway
  - Darker line is shear data (reflective of strategy)
    - This patient’s data shows more shear on SOT6 (hip strategy)
  - Lighter line is postural sway pattern
    - Up is anterior sway (max is 8°)
    - Down is posterior sway (max is 4.5°)
Example Case: SOT

► This is the raw data for the COG Trace for a patient with a normal SOT
► A plus (+) marks the center of the force plate
► Sway occurs in the anterior-posterior direction

Example Case: SOT

► This is the comprehensive score report for a patient with an abnormal SOT
► This patient has difficulty with use of vestibular input
  ► Falls on test conditions 5 and 6
  ► “Vestibular Pattern”
► Also note: abnormal composite score, patient attempted to use an ankle strategy when falls occurred, abnormal COG alignment (too anterior and left)
Example Case: SOT

- This is the raw data for a patient with an abnormal SOT
  - Falls on test conditions 5 and 6

- This is the raw data for the COG Trace for a patient with an abnormal SOT
  - Falls on test conditions 5 and 6
  - A plus (+) marks the center of the force plate
    - Same alignment noted (too anterior and left)
  - Sway occurs in the anterior-posterior direction
Example Case: SOT

- This is the comprehensive score report for a patient with an abnormal SOT

- This patient has many trials with below-normal performance, and one fall (SOT5, trial 1)

- Abnormal composite score

Case Example: SOT

- This is the comprehensive score report for a patient with an abnormal SOT

- This patient has difficulty with sway referenced (compliant) surfaces
SOT - Does it relate to function?

- SOT5 scores correlate with abnormal utricular function as measured by subjective visual vertical (Goebel, 2005)
- SOT5 score changes correlated with Vestibular Disorders Activities of Daily Living (VADL) score changes as a measure of function (Cohen, 2004)
  - if initial SOT5 score was low, then increased changes were seen with VADL
  - if initial SOT5 score was high, then little change was seen with VADL

Motor Control Test (MCT)

- Patient’s postural reactions; ability to recover balance
- Unexpected, abrupt movements of the force plate support surface
- Small, medium, and large translations forward and backward
- Measures:
  - Onset timing of patient-generated response
  - Strength of response
  - Symmetry (left and right) of response
MCT: Two Testing Conditions

1. [Diagram of Forward Translation]
2. [Diagram of Backward Translation]

Forward/Backward Translations

MCT Comprehensive Report

- Weight Symmetry - quantifies the relative distribution of body weight on each leg
- Latency - quantifies the time between translation of the support surface and initiation of the patient’s motor response
  - Composite Latency Score
- Amplitude Scaling - quantifies the strength of motor responses (force production) for both legs and for the three translation sizes

(NeuroCom, 2015)
MCT Comprehensive Report

- Normal automatic motor response
  - Composite latency Score: green is a normal test
  - Small translations result in little to no measurable responses
  - Large translations result in slightly faster (smaller latency) responses than medium translations
  - Responses are symmetrical between left and right sides
  - Responses occur in <150 msec
  - Amplitude increases in relation to translation size
Adaptation Test (ADT)

- Patient’s postural reactions; ability to adjust motor responses and sway
- Unexpected, abrupt movements of the force plate support surface
- Toes-up and toes-down rotations

Measures:
  - Magnitude of response (force)

ADT: Two Testing Conditions

1. Toes Up and Toes Down Rotations
2. (NeuroCom, 2015)
ADT Comprehensive Report

- Toes Up & Toes Down - depicts the magnitude of the force response required to overcome sway induced by rotation of the support surface.

- Averaged, Raw Sway, and Center of Force
  - Sway Energy - a measure of the force generated by the patient during the initial 2 seconds following the stimulus.

- Normal automatic motor response
  - Sway Energy Scores are higher during initial trials and decrease progressively.

ADT Comprehensive Report

Adaptation Test

![Graph showing TOES UP and TOES DOWN with data points and lines indicating sway, total force, and average data. Diagram includes notes: 5 degrees 20 lb force 4 in force center displacement error 2.5 seconds Sampling rate 100 Hz.]

Continued
Example Case: ADT

- This patient fell on the first trial of the Toes Up condition
- Notice the computer marks this as a “FALL”

Main Menu (for Current Patient) Screen for NeuroCom EquiTest
Selecting “Analysis” will allow the Audiologist to view the comprehensive reports and raw data for the SOT, MCT, and ADT tests.
Clinical Utility of CDP

- Aid in diagnosis of a health condition
- Documentation of balance impairments and progression
- Treatment planning and monitoring
- Suspicion of symptom magnification
  - Large inter-trial variability
  - Repetitive anterior-posterior sway without falling
  - Medial-lateral sway
  - Better performance on more difficult test conditions
  - Exaggerated responses to small perturbations on the MCT
  - Inconsistent responses to small and large perturbations on the MCT
Thank You

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References

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