Vestibular Retraining Therapy and Falls Reduction

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COI

- Nothing to declare
- I hired a statistician
- Navid Shahnaz PhD assisted with VEMPs
- Undergraduate students assisted with subject registration, telephone follow up

Observations before the study

- Vertigo prevalence is 35%, increasing
- an important cause of disability: associated with depression, anxiety and cognitive deficits
- UVD prevalence approx. 1% in young adults climbing to over 6% for those over 70
- Direct medical costs is 60B/yr
- Increased falls risk causing 700,000 deaths globally and 1% of health care costs
- World guidelines on treatment are based on exercises from the 1940s
- 2/3 of people do not improve

Evidence before the study

- There are two high quality systematic reviews on the topic of vestibular rehabilitation showing moderate to strong evidence that it is safe and effective for improving symptoms, visual impairment, balance, gait and adl;
- however most studies were limited by subjective outcome measures only, and a variety of causes of dizziness
- Paucity of objective balance metrics

Added value of this study

- The studies enrolled an important group of patients – those with persistent symptoms caused by objectively confirmed UVD who continue to experience life-limiting symptoms despite previous treatment with recommended therapy
- In the pilot, we asked, 'What effect does CVRT have before and after treatment?' We did not have a placebo/sham/no treatment control in the pilot, because we designed the studies in accordance with the CPG recommendation that trials should compare between treatments, not against no treatment

Computerized Vestibular Retraining Therapy

- Rehabilitation interventions using CDP are uncommon, although this modality has shown promise in a small number of studies for indications such as central vestibulopathy and Parkinson's disease as well as for reducing fall risk in elderly individuals.

Computerized Vestibular Retraining Therapy

- Augmented biofeedback and VR
- Participants were challenged to shift their weight forward and backward and right to left as directed by an interactive display or to maintain their balance while the support surface moved.
- The display also provided a visual representation of the center of gravity as a biofeedback aid for their postural control.
- The exercises grew progressively more difficult over the course of the treatment protocol.
- The exercise programs were predetermined, and each participant received the same protocol except to account for the laterality of their deficit.

Longitudinal cohort single group pilot studies (2021-22)

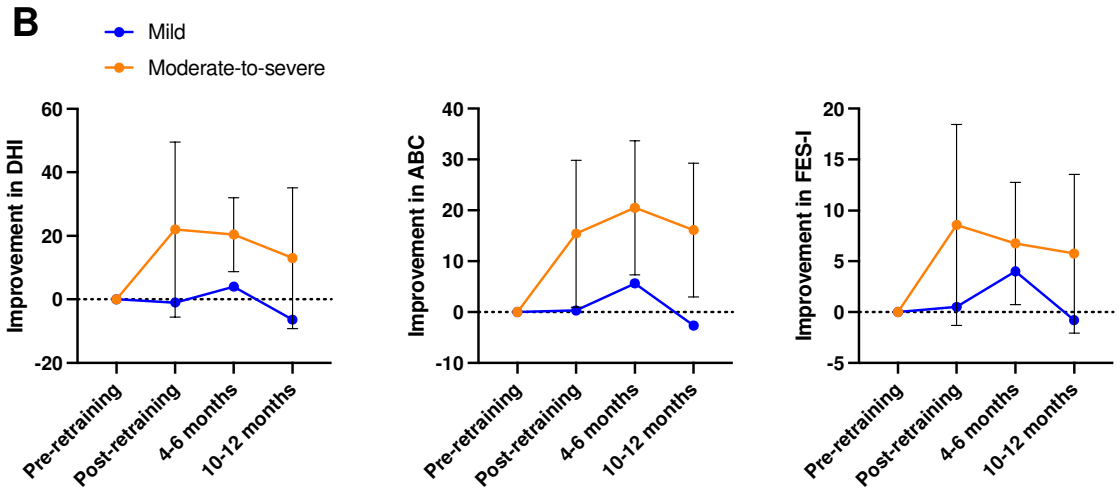
- 13 patients with stable unilateral vestibular deficits
- Received 12 sessions of CVRT and were followed for up to 1 year

- JAMA Otolaryngol Head Neck Surg. 2022;148(5):426-433. doi:10.1001/jamaoto.2022.0167. Views 1,231 Citations 6
- JAMA Otolaryngol Head Neck Surg. 2022;148(9):888-889. doi:10.1001/jamaoto.2022.1953. Views 635 Citations 1
- JAMA Podcast JAMA Otolaryngology–Head & Neck Surgery
- Published Online: March 31, 2022 Audio Author Interview 15 min 36 sec
- NeuroRehabilitation. 2023;52(2):279-287. doi: 10.3233/NRE-220241.
- Acta Otolaryngol. 2023 May;143(5):396-401. doi: 10.1080/00016489.2023.2208615. Epub 2023 May 12
- Otolaryngol Head Neck Surg. 2023 Aug 2. doi: 10.1002/ohn.462. Online ahead of print

CVRT and Disability Measures

- 12 biweekly sessions of CDP-guided vestibular retraining exercises in the clinic. These exercises were designed in accordance with the accepted principles of vestibular rehabilitation to promote compensation (or habituation) and substitution.
- 3 questionnaires: the Dizziness Handicap Inventory (DHI), the Activities-Specific Balance Confidence (ABC) Scale, and the Falls Efficacy Scale–International (FES-I).

CVRT improved patient-reported measures for patients with moderate-to-severe disability



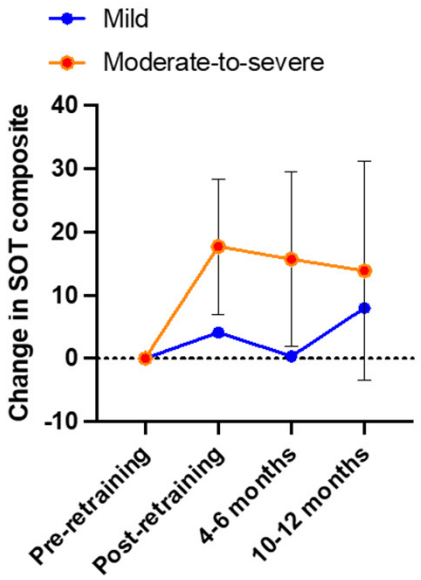
Disability after CVRT

- After treatment, DHI, FES-I, and ABC Scale scores improved, with median changes in scores of −16 points (95% CI, −20 to 2) for the DHI, −9 (95% CI, −14 to 1) for the FES-I, and 11.9 (95% CI, 0-17.3) for the ABC Scale
- Among those with moderate to severe disability at baseline, the median magnitude of improvement in all scores was greater than for those with mild disability
- Participants with moderate to severe disability at baseline had a larger magnitude of improvement in DHI scores than those with mild disability

DHI after CVRT

- The DHI measures self-perceived disability in 3 domains: physical, emotional, and functional.
  - For those with baseline DHI scores greater than 30, there was improvement of −14 points (95% CI, −36 to −2) in the functional domain, whereas improvement in the physical domain was −4 (95% CI, −24 to 2) and improvement in the emotional domain was −10

CVRT improved objective measures for patients with moderate-to-severe disability



CVRT decreased response variance of posturography testing

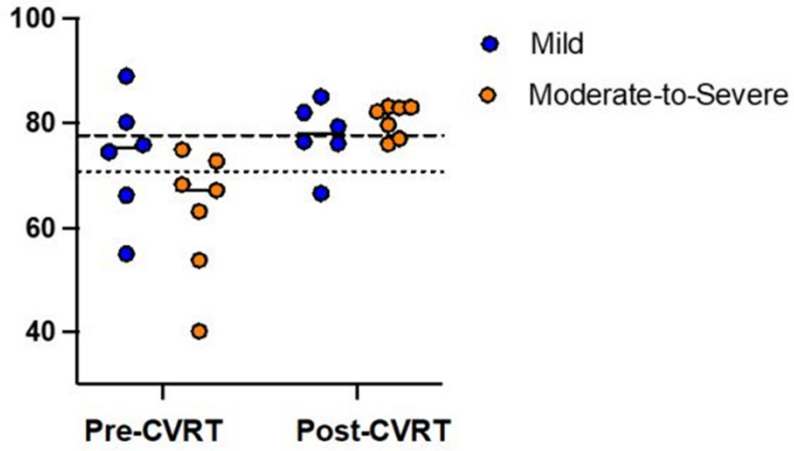
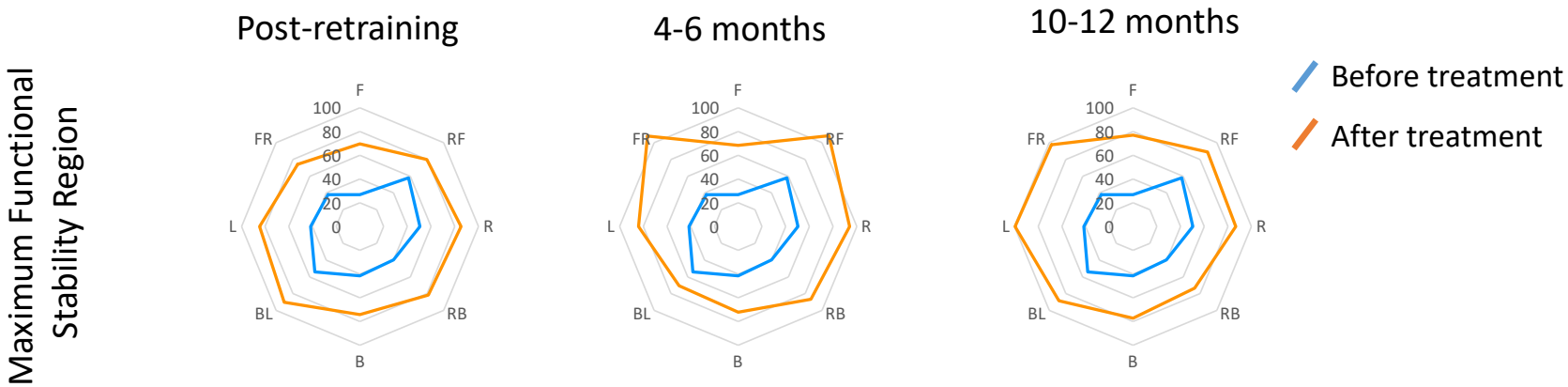


Figure 3 Scores for the SOT composite score for participants with mild disability (DHI ≤ 30; n=6; blue circles) compared to moderate-to-severe disability (DHI > 30; n=7; orange circles). Normative mean (heavy dashed line) and 1 standard deviation below the mean (light dashed line) are indicated for each condition and the composite score.

Fall Risk – Functional Stability Region (FSR)

- The LOS test assesses volitional displacement of center of gravity in the lateral and anteroposterior directions.
- The displacement achieved relative to the theoretical limit can be used to calculate an individual's FSR, which is lower among those with unilateral vestibulopathy.
- A smaller FSR implies a constant state of being about to fall
- Interventions that increase the FSR are posited to reduce the risk of falls

CVRT increased Maximum Functional Stability Region which is correlated with Falls Risk



Findings from single group pilot studies

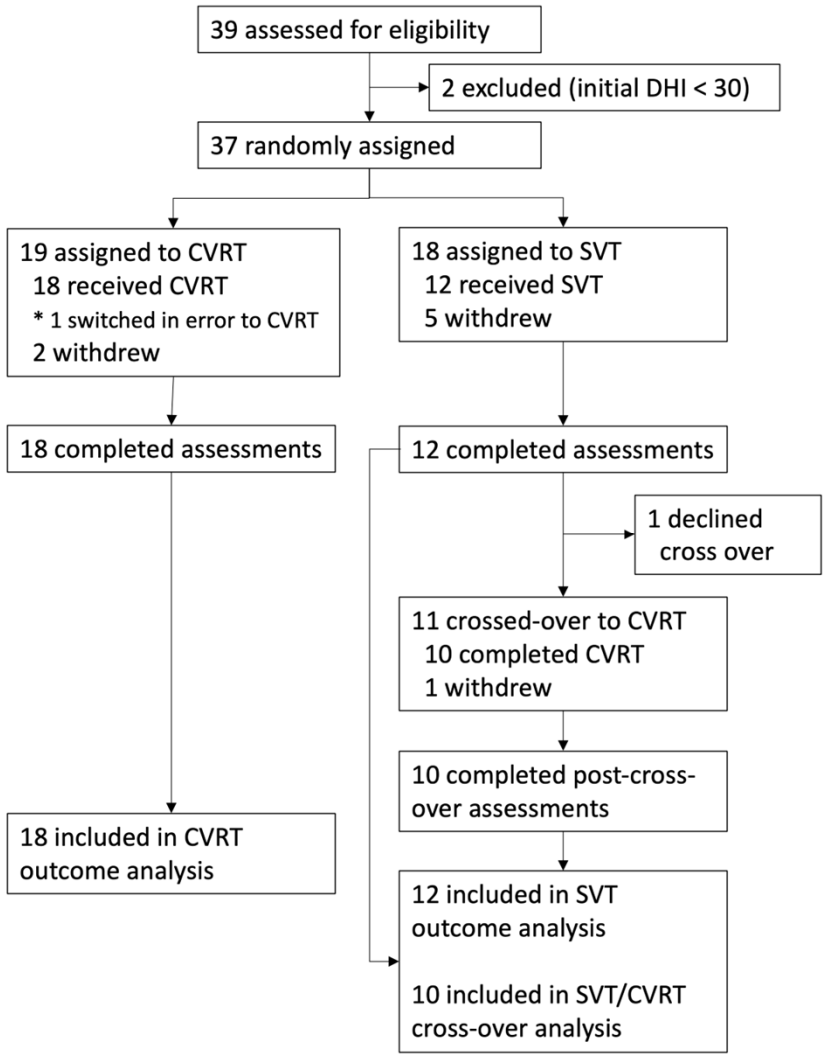
- Durable improvement of objective and subjective measures
- Better results for patients with moderate-to-severe symptoms than for patients with mild symptoms

- These findings went on to inform design of an RCT

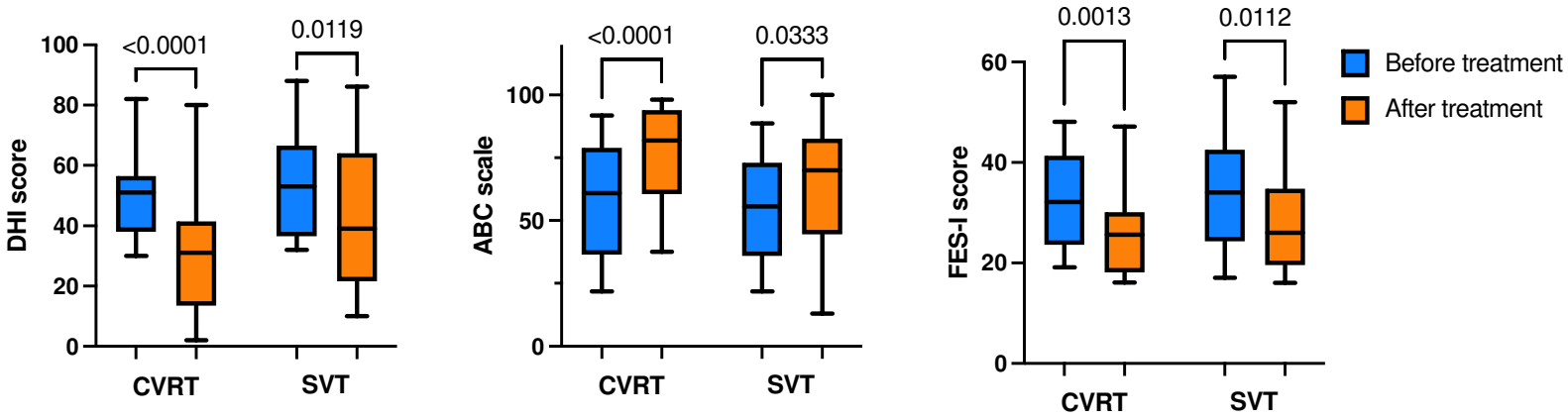
Randomized controlled trial of CVRT compared to standard vestibular therapy (SVT)

- Enrolled 37 patients (18 completed CVRT, 12 completed SVT, 7 withdrew)
- SVT group was offered CVRT after completing control intervention

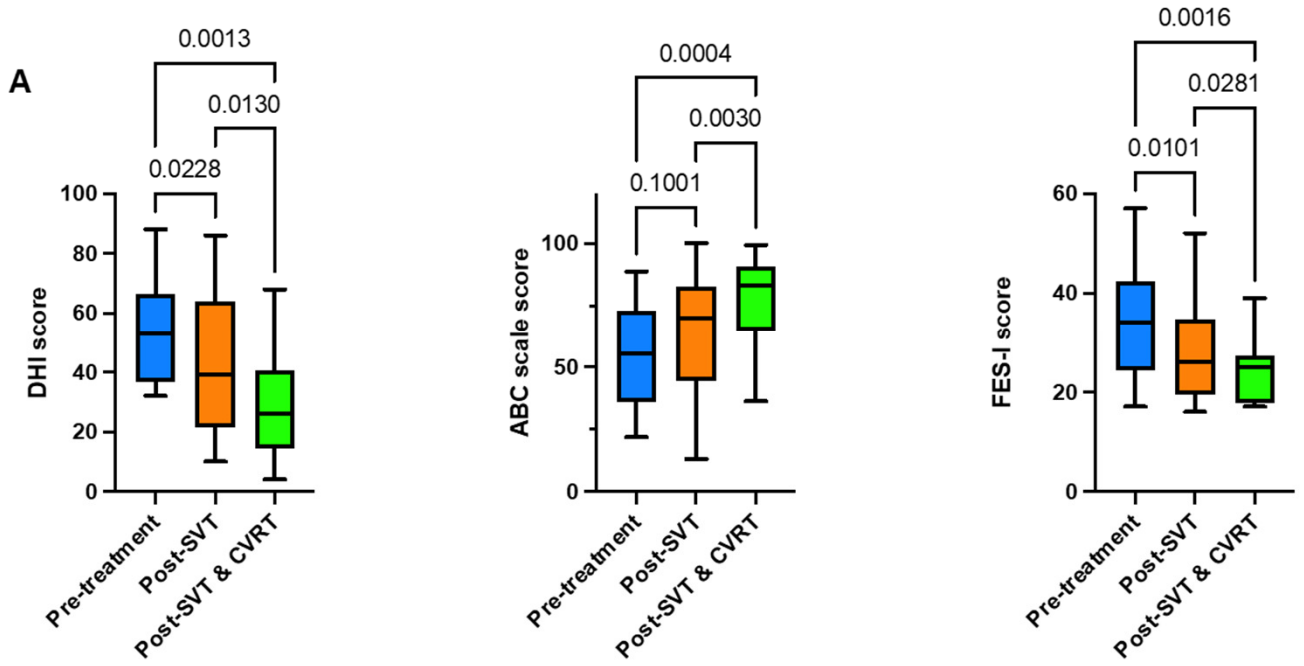
- Enrolment (37 patients enrolled)
- 18 received CVRT; 12 received SVT
  - 7 withdrew
- Outcome measures
  - Objective posturography (SOT, FSR)
  - Patient-reported (DHI, ABC, FES-I)
- 10 patients from SVT crossed over to CVRT



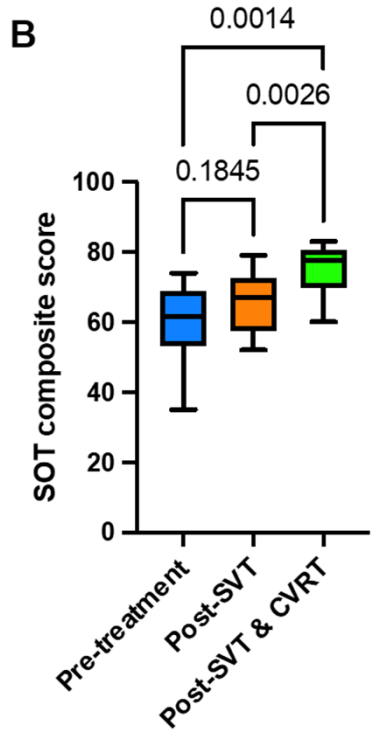
CVRT and SVT improve patient-reported measures but CVRT improvement is greater



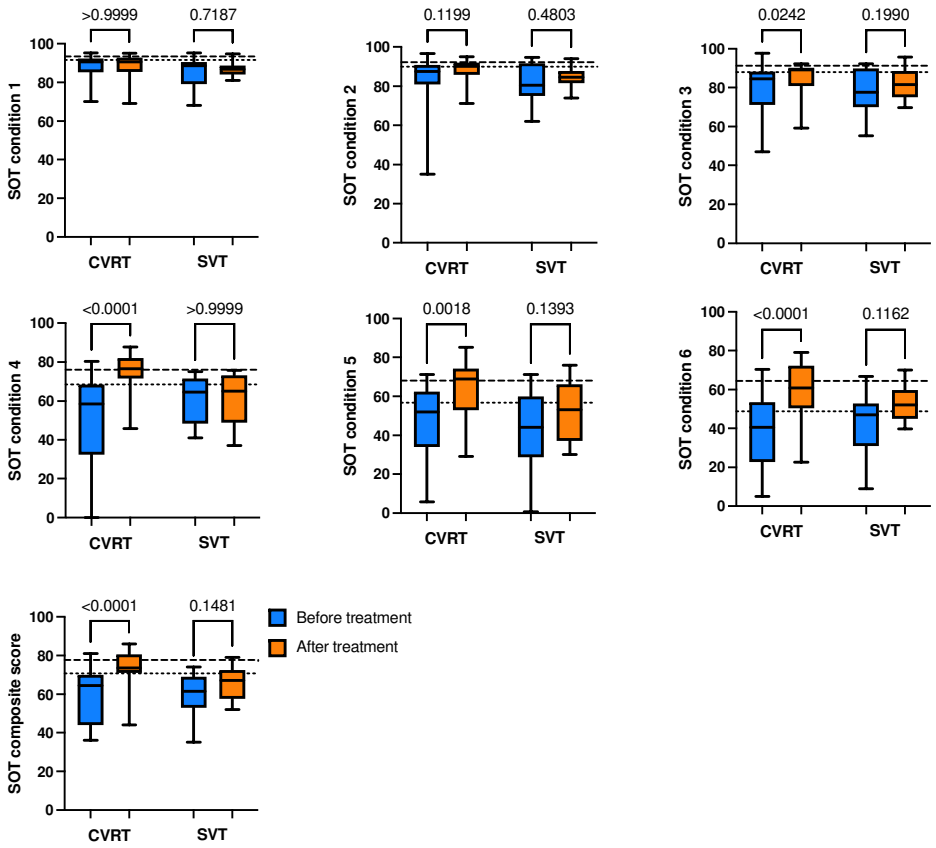
Cross-over to CVRT after SVT improves patient-reported measures compared to SVT alone



Cross-over to CVRT after SVT improves objective posturographic measures compared to SVT alone



After CVRT, but not SVT, posturography scores are similar to normative values



CDP Submeasures

- When the platform remained fixed (SOT conditions 1 to 3), allowing for reliable somatosensory information, median values were not significantly different from published normative data for individuals with no documented vestibular deficit. These scores did not improve with CDP-assisted retraining.
- No change in SOT 1- 3 suggests that there is no “learning effect”
- This is consistent with reports that show static balance frequently resolves spontaneously in days or weeks, whereas dynamic balance, which involves integrating sensory cues that may be in conflict, resolves slowly or incompletely.

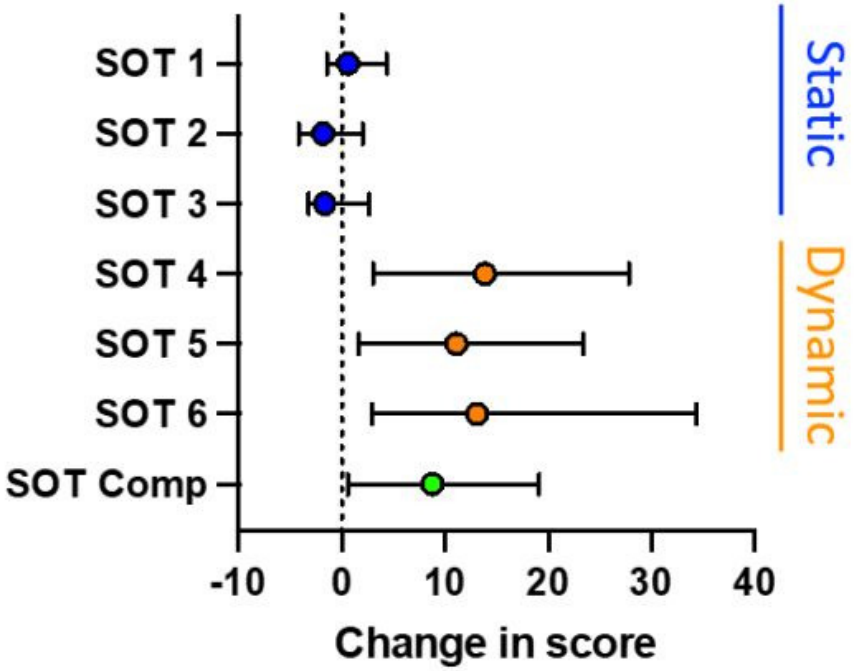
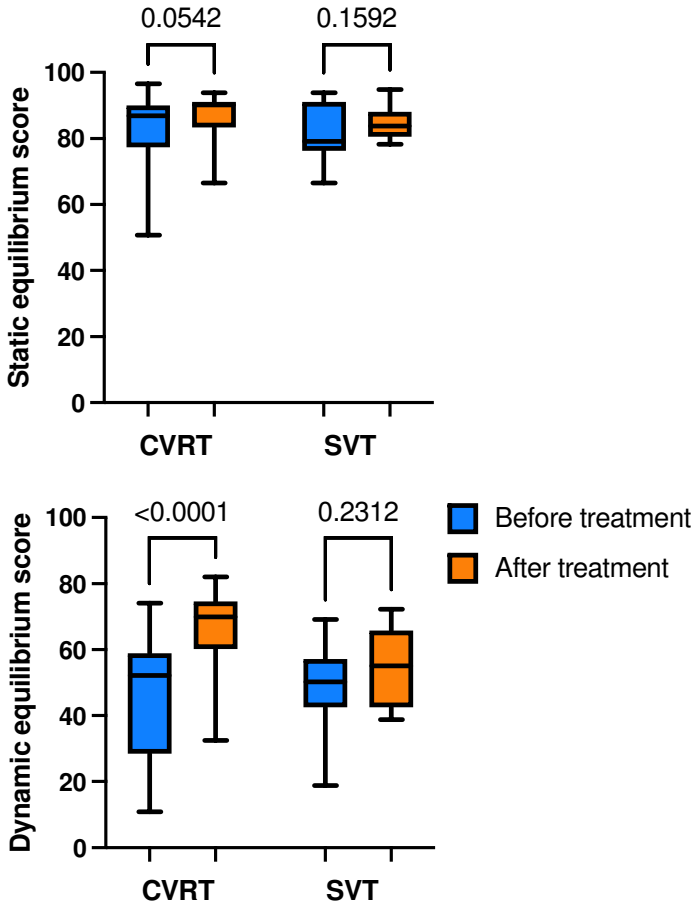


Figure 1 Change in score for SOT conditions 1-3 (static platform, blue), 4-6 (dynamic platform, orange) and composite score (SOT Comp, green). Points indicate the median change and bars indicate 95% confidence interval.

CVRT improves dynamic balance

- Defined conditions 1-3 (stable underfoot platform, with or without reliable visual cues) as the STATIC EQUILIBRIUM SCORE

- Defined conditions 4-6 (sway referenced underfoot platform, with or without visual cues) as the DYNAMIC EQUILIBRIUM SCORE



Current standard treatments

- While Cawthorne-Cooksey style exercises are strongly recommended, 33%-63% of patients report no benefit
- Approximately 32% continue to have moderate or severe symptoms following treatment
- The benefits of a tailored approach cannot be differentiated from the benefits of close therapist supervision
- Improved technique and compliance increases the treatment dose

Underlying principles of vestibular rehabilitation

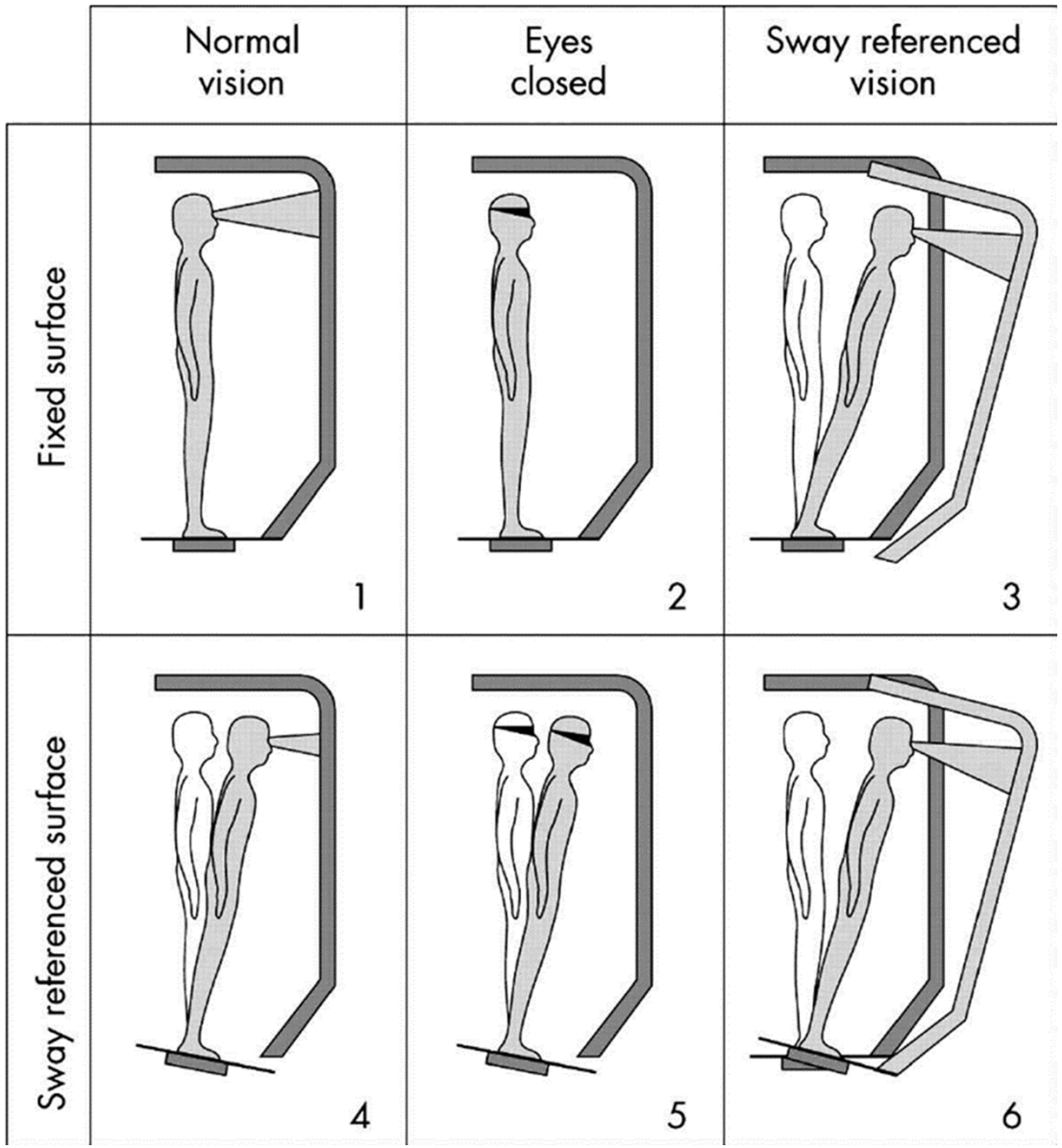
- Adaptation: Encouraging plasticity to improve the brain's ability to compensate for vestibular deficits.
- Substitution: Training other sensory systems (vision and proprioception) to compensate for vestibular loss.
- Habituation: Gradually exposing patients to motion-provoking stimuli to reduce sensitivity

What is the source of improvement?

- Status quo is that there's no real regain of function after rehabilitation exercises, and these individuals would be expected to struggle in situations of conflicting sensory input or in dynamic challenges to postural stability.
- Evidence for this included observations that VOR gain in response to head accelerations does not recover and that nystagmus persists in dark environments, even when patients no longer complain of oscillopsia or blurred vision.
- Thus, the current opinion is that sensory inputs other than vestibular organs are driving recovery of gaze stability.

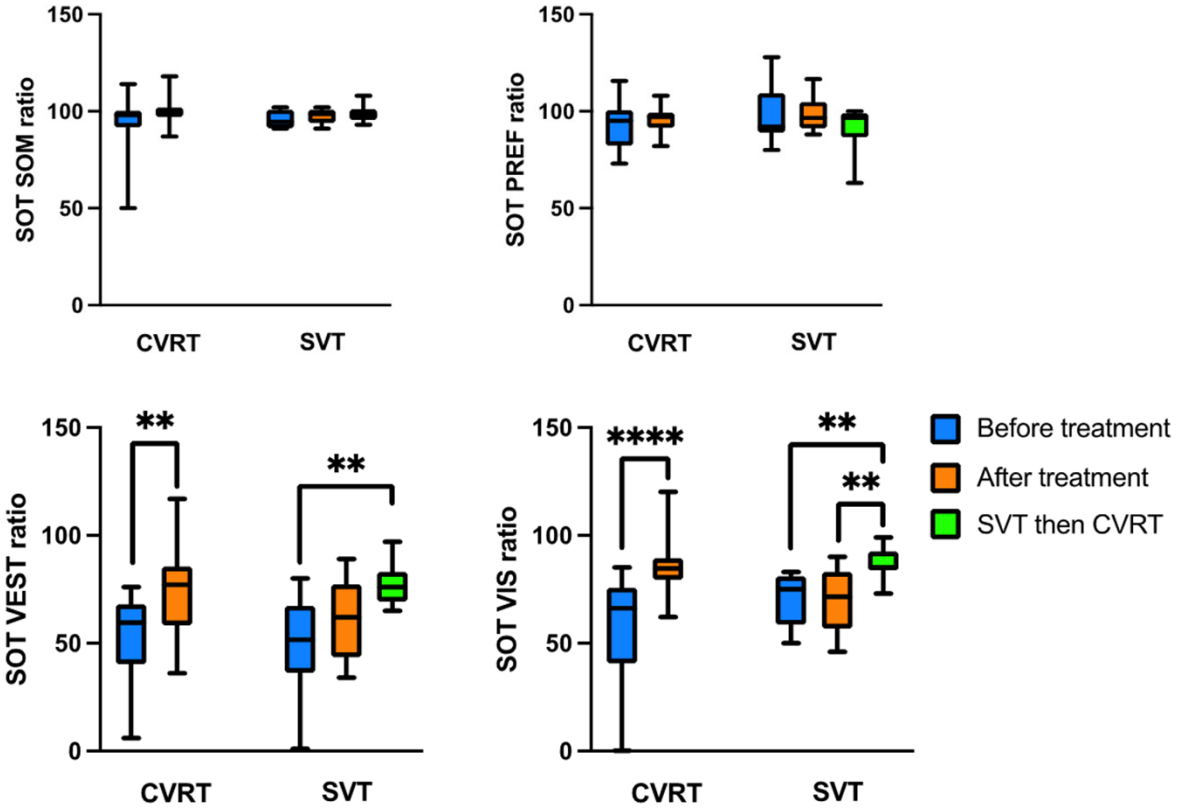
SOT ratios: isolate sensory inputs

- The individual conditions of the SOT challenge the participant to maintain equilibrium with a full complement of somatosensory, visual, and vestibular information and then systematically removes or creates sensory conflict with the somatosensory and visual information. Ratios of these scores indicate the use of one sensory input over another.
- SOM = somatosensory (SOT 2/1)
- VIS = vision plus vestibular (SOT 4/1)
- VEST = vestibular only (SOT 5/1)
- PREF = visual preference only (SOT 3+6/2+5)


Normal vision
Eyes closed
Sway referenced vision
Fixed surface
Sway referenced surface
1
2
3
4
5
6

CVRT, but not SVT, is associated with improved vestibular sensory ratios

Both groups performed well before treatment for SOM (ie. good static balance on stable platform) and PREF (ie. no strong visual preference) and neither changes with treatment
VEST and VIS (both reflect performance on an unstable, sway referenced platform) improve with CVRT but not SVT



The role of vision is not supported

- Participants were better able to tolerate absent visual information (eyes closed) or conflicting visual information (sway referenced visual surround) after retraining, demonstrating that their improved postural control was not reliant on visual information.

If not vision then what is driving the findings

- After retraining, SOT and LOS scores compared well with published age-matched values for individuals with no vestibular deficit.
- The ranges and confidence intervals between participants, which had been very wide prior to retraining, decreased significantly

Results imply Vestibular Sensory Reweighting

- Taken together, these findings suggest that after computerized vestibular retraining, participants were weighting information from their vestibular organs – either on the unaffected side or from intact organs on the affected side – over vision.
- The data suggests: substitution to contralateral vestibular organ or restoration of ipsilateral vestibular function in our subjects.

In general

- Our ability to diagnose has outpaced our ability to treat
- Worldwide balance loss is a major modifiable risk factor for falls
- We need to address inconsistent patient populations in the literature
- We need to quantify stability, and apply outcome metrics
- SOT/SR/LOS are objective metrics as adjuncts to the current standards of care which rely on: performance and disability questionnaires

Specifically

- Balance and stability can be measurably improved
- Fall risk can be measurably reduced
- The changes appear durable
- The mechanism appears to be plasticity of vestibular pathways
- “Retraining” appears more precise than “rehabilitation”

Limitations

- Single center
- Moderate sample size
- Didn’t include geriatric measures such as TUG, DGI, BBT
- But GOAT objective metric: VOR Gain

VOR Gain

- VOR testing using VHIT is complicated by unclear normative data and high test artifact
- Mantokoudis (2015) identified a 44% incidence of test artifact in over 1500 patients
- Most literature has been using VOR gain less than .80 to indicate pathology
- Barany Consensus statement (2022) identified VOR gain less than .7 and large amplitude refixation saccades (RS) to be necessary

VOR gain as an objective metric

- Most studies, including the RCTs dealing with VR vestibular rehabilitation (Micarelli 2019) have used .80 cutoff only, without clear discussion of RS
- VOR gains between .7-.8 have a high incidence of false positives (Shupak 2023)
- Even when using VOR .72 only, the sensitivity of VHIT is only 80%

VOR gain assessment

VOR abnormality must first be determined by:

- Gain less than .72
- RS frequency greater than 80% (ie 100% indicates a RS for each individual head impulse)
- Velocity equal or greater than the VOR

- With the first two criteria being critical

VOR gain as the ideal physiologic metric

An ideal physiologic metric for VOR improvements would be the demonstration of:

- Improving VOR gain
- Decreasing velocity of RS
- Decreasing frequency of RS
- Shifting of RS pattern from clustering to disorganized as evinced over time in patients post vestibular schwannoma removal (Curthoys 2023)
- These changes have not been recorded post vestibular rehabilitation

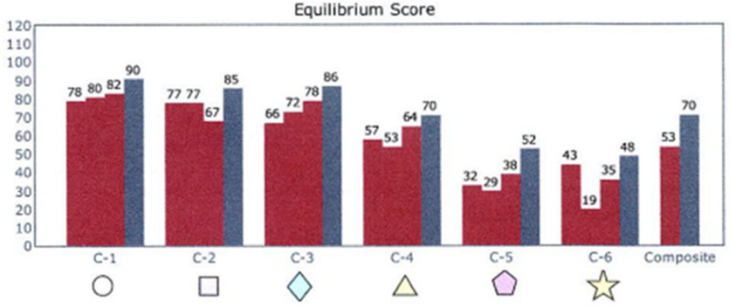
- …*For current purposes it appears that SOT/LOS/SR represent good functional outcome metrics, especially for dynamic stability measurements*

Patient Information		
Name:		**Height:** 5'3", **Weight:** 139.0 lbs, **BMI:** 24.7
Identifier: CDPR-9Z	**Sex:** F	**Date of Birth:** 1992/05/20

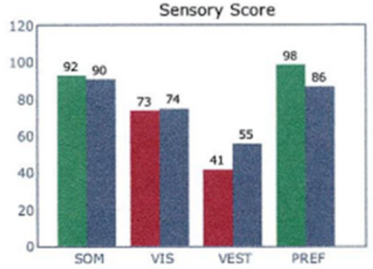
Patient Notes
oVEMP left weakness

Sensory Organization Test Report - Mar 7, 2022

Equilibrium Score



Sensory Score

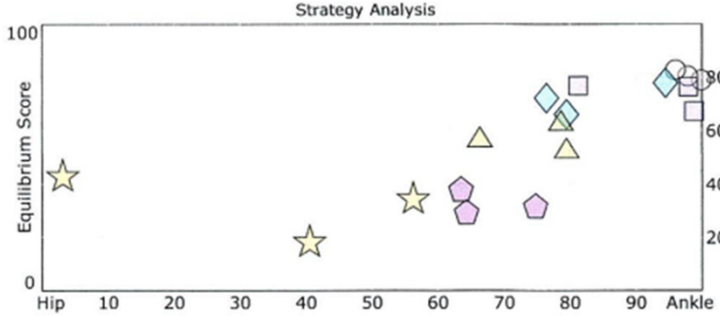


C-1 = Condition 1, **C-2** = Condition 2, **C-3** = Condition 3, **C-4** = Condition 4, **C-5** = Condition 5, **C-6** = Condition 6
SOM = Somatosensory, **VIS** = Visual, **VEST** = Vestibular, **PREF** = Preference, **COG** = Center of Gravity

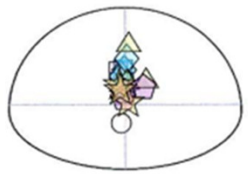
Trial Times (seconds)

Condition 1		Condition 2		Condition 3		Condition 4		Condition 5		Condition 6							
20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20

Strategy Analysis



COG Alignment

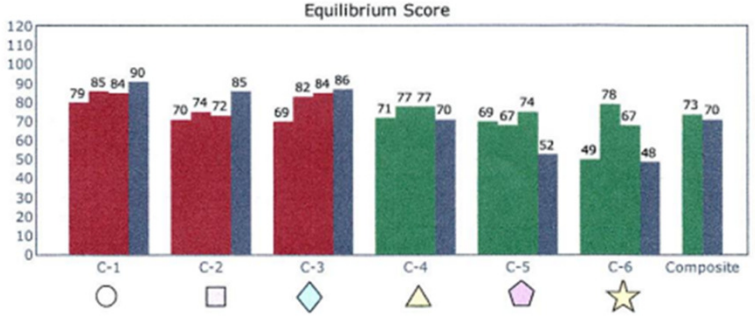


Patient Information		
Name:		**Height:** 5'3", **Weight:** 135.9 lbs, **BMI:** 24.1
Identifier: CDPR-9Z	**Sex:** F	**Date of Birth:** 1992/05/20

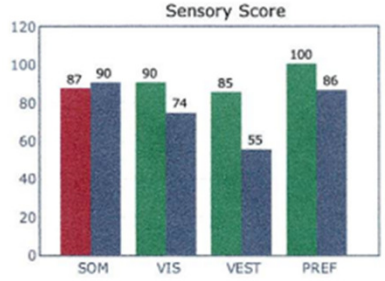
Patient Notes
oVEMP left weakness

Sensory Organization Test Report - Apr 28, 2022

Equilibrium Score



Sensory Score



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20	20	20	20	20	20	20	20	20	20	20	20

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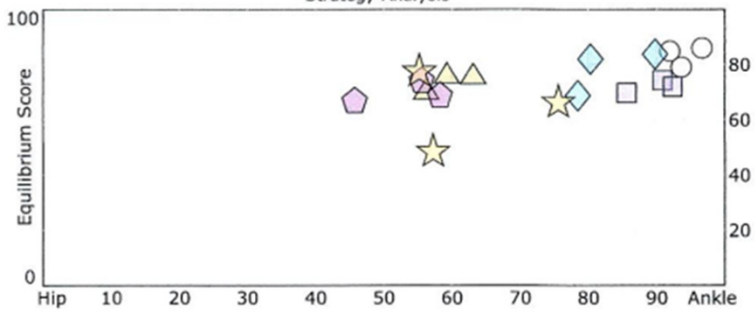

COG Alignment