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CONTINUED

Neuroplasticity in vestibular impairment

The foundation and facilitatory techniques for optimizing healing

Janene M. Holmberg, PT, DPT, NCS

Intermountain Hearing and Balance Center

Salt Lake City, Utah

3

CONTINUED

Intermountain Hearing and Balance Center

Salt Lake City, Utah

4

CONTINUED

Objectives/Learner Outcomes

- Establish the language of vestibular anatomy and pathophysiology
  - Participants will be able to describe key anatomical and neurophysiologic responses unique to the vestibular system
- Discuss the **evidence for robust inherent plasticity/ healing** with respect to the vestibular system
  - Participants will be able to express 3 principals that drive vestibular rehabilitation exercise prescriptions including understanding best evidence for optimal dosing

5

Objectives/Learner Outcomes

- Discuss **key components of the clinical bedside** vestibular exam for identifying vestibular impairment
  - Participants will be able to ID at least 3 clinical test findings supporting vestibular impairment and need for vestibular rehabilitation exercise prescriptions
- Discuss specific treatment techniques that have been found to be most powerful in optimizing healing and reducing vestibular-specific disability
  - Participants will be able to prescribe, at optimal dose and intensity, 3 vestibular-specific exercise paradigms

6

General Incidence

- Dizziness/Imbalance is a **common complaint**
- **8 million primary care visits annually**
- **#1 Reason** for someone >75 yrs old to consult a physician
  - Furman et al 2010, Curr Opin Otolaryngol HNS 18:386-91
- Persons with dizziness rate lower quality of life
  - Neuhauser et al, 2008
- Vertigo and Dizziness contribute to disability
  - Mueller M et al 2013
- 86% experience interrupted activities of daily living or lost work
  - Van Beuren, 2007

7

General Incidence

- 42% of population (90 million) will c/o at least once in their lifetime (NIH)
- Dizziness one most frequent c/o in Primary Care often remains unexplained(40-80%)
  - Kroenke K 1993, Bird JC 1998
- **Vestibular pathology** as cause of dizziness
  - <65 yo is 38% (Baloh)
  - **Incidence of vestibular dysfunction** increases with age to 50%-60%

8

BOTTOM LINE…..

- DIZZINESS is Common
- DIZZINESS is Disabling
- DIZZINESS IS often secondary to vestibular disorders from a variety of causes

9

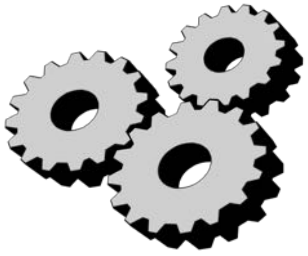
What makes Vestibular Rehabilitation work??

- Vestibular system is vulnerable to biomechanical insults, neurovascular, and central processing
  - Unique interventions required for different insults
- Skilled differential clinical testing & quantifying impairments
  - Optimal treatment paradigms and exercise prescription
- Neuroplasticity and Direct mechanical repositioning

10

Before we dive into the role of Plasticity & Adaptation….

Role of Biomechanics in Vestibular Rehabilitation



11

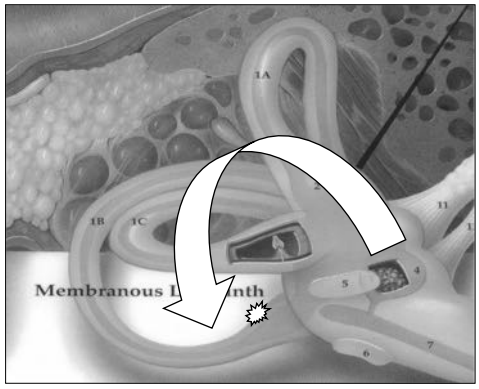
Benign Paroxysmal Positional Vertigo (BPPV)

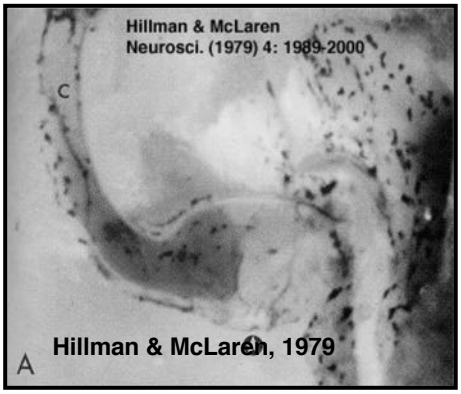
- BPPV is the most common vestibular disorder across the life span and most common cause of recurrent vertigo
  - Secondary to displaced otoconia from the utricle into one of the semicircular canals, most commonly the posterior
- Dizziness secondary to BPPV, accounts 17-42% of cases
  - Bhattacharyya N, 2008
- High success rates (80%) with 1-3 treatments when correctly ID and treated

12

BPPV is caused by displaced otoconia from the utricle most commonly into the posterior canal

Only one way OUT

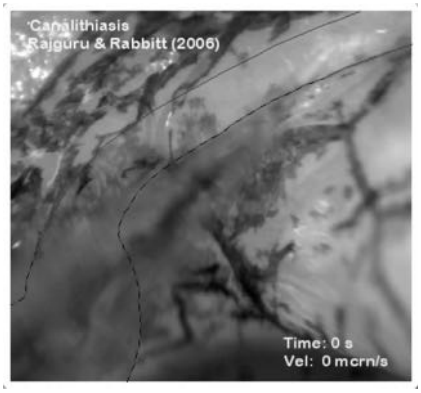


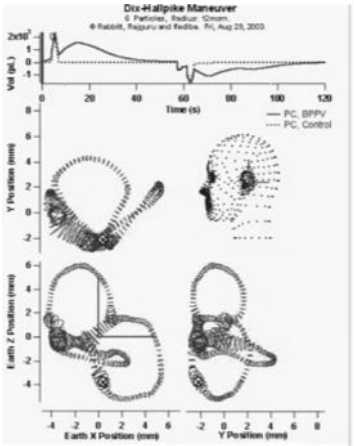


Benign Paroxysmal Positional Vertigo (BPPV)
Canalith Repositioning Treatments Maneuvers

13

Biomechanical physics of BPPV (Rabbitt)





14

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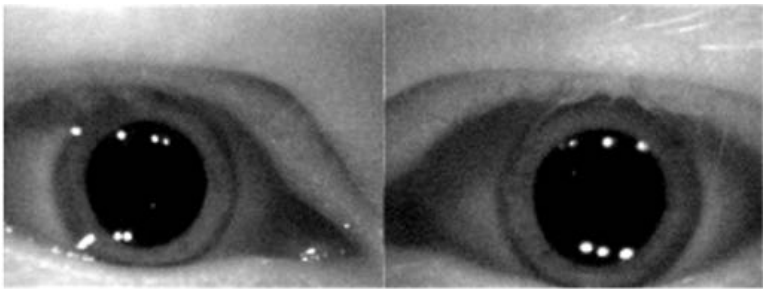
DIX-HALLPIKE TESTING



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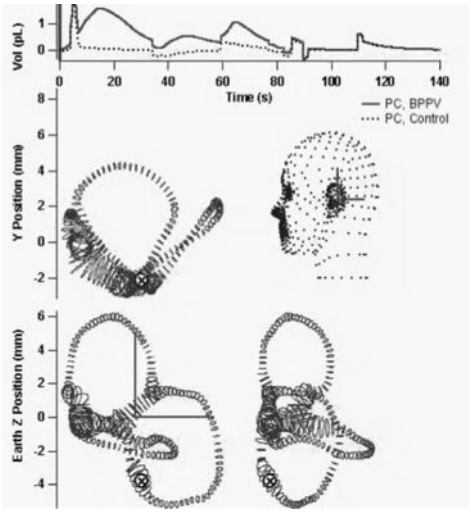
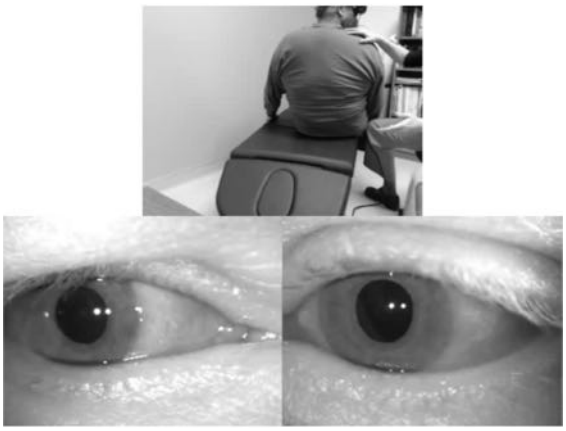


Biomechanics of canalith repositioning maneuver

R. Rabbitt

16

Canalith Repositioning Treatment or Epley Maneuver



17

Changing Maneuver Based on Quality of Eye movement

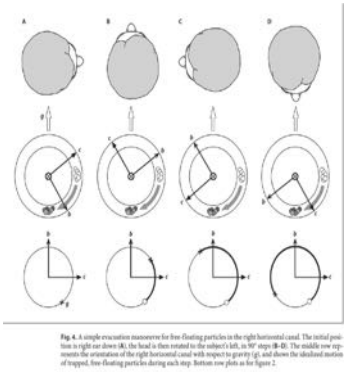
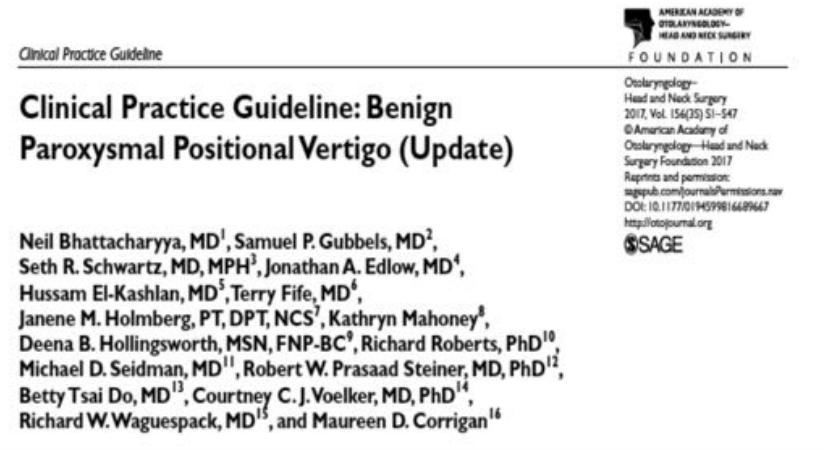


Fig. 4. A simple evacuation manoeuvre for free-floating particles in the right horizontal canal. The initial position is right ear down (A), the head is then rotated to the subject's left, in 90° steps (B–D). The middle row represents the orientation of the right horizontal canal with respect to gravity (g), and shows the idealised motion of trapped, free-floating particles during each step. Bottom row plots as for figure 2.

18

Evidence for BPPV



Clinical Practice Guideline

Clinical Practice Guideline: Benign Paroxysmal Positional Vertigo (Update)

Neil Bhattacharyya, MD[1], Samuel P. Gubbels, MD[2], Seth R. Schwartz, MD, MPH[3], Jonathan A. Edlow, MD[4], Hussam El-Kashlan, MD[5], Terry Fife, MD[6], Janene M. Holmberg, PT, DPT, NCS[7], Kathryn Mahoney[8], Deena B. Hollingsworth, MSN, FNP-BC[9], Richard Roberts, PhD[10], Michael D. Seidman, MD[11], Robert W. Prasaad Steiner, MD, PhD[12], Betty Tsai Do, MD[13], Courtney C. J. Voelker, MD, PhD[14], Richard W. Waguespack, MD[15], and Maureen D. Corrigan[16]

AMERICAN ACADEMY OF OTOLARYNGOLOGY—HEAD AND NECK SURGERY FOUNDATION

Otolaryngology—Head and Neck Surgery
2017, Vol. 156(3S) S1–S47

DOI: 10.1177/0194599816689667
http://otojournal.org
SAGE

19

Benign Paroxysmal Positional Vertigo (BPPV)

- *"There is NO evidence.. to suggest that any.. medications are effective as a primary treatment or as a substitute for a repositioning maneuver"*
- Repositioning maneuvers are different from Cawthorne-Cooksey or Brandt-Daroff exercises
  - Bhattacharyya N et al 2017
- Single canalith repositioning maneuver is >10 times more effective than 3 times a week Brandt Daroff exercises
  - Hilton MP et al, 2014
- Success at 80.5% with the canalith repositioning maneuver vs 25% success with the Brandt Daroff exercise
  - Amor-Dorado JC 2012

20

CONTINUED

Vestibular Healing

- Full recovery is **movement-dependent**
  - "cellular recovery" only responsible for re-establishment of the tonic firing rate (spontaneous)
- **Stimulus-specific**
- "Repair"often requires **profound reorganization** of central pathways
- Driving stimulus: **error message**
  - VOR: retinal slip
  - VSR: induced postural disturbances, sensory mismatch
  - recalibration of movement cues

Role of Habituation, Adaptation, and systematic Desensitization

21

CONTINUED

Vestibular Healing (cont.)

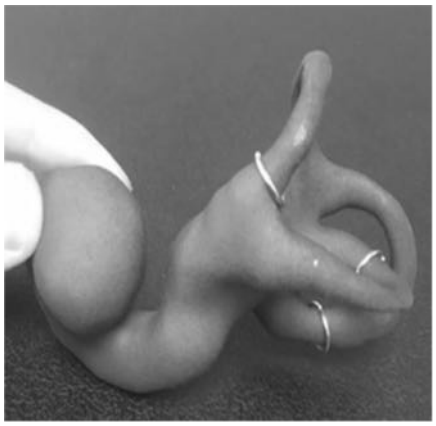
- Special role of **vision & cerebellar pathways**
  - Lacour & Xerri 1981
  - Recovery rate slowed by one eye covered
  - Requires intact occipital lobe function
- **Critical period** of recovery
  - Lacour 1984
  - McCabe 1972, Zee 1988
    - theorized to coincide with inhibition of vestibular nuclei
    - influence by medications

22

Vestibular Anatomy 101

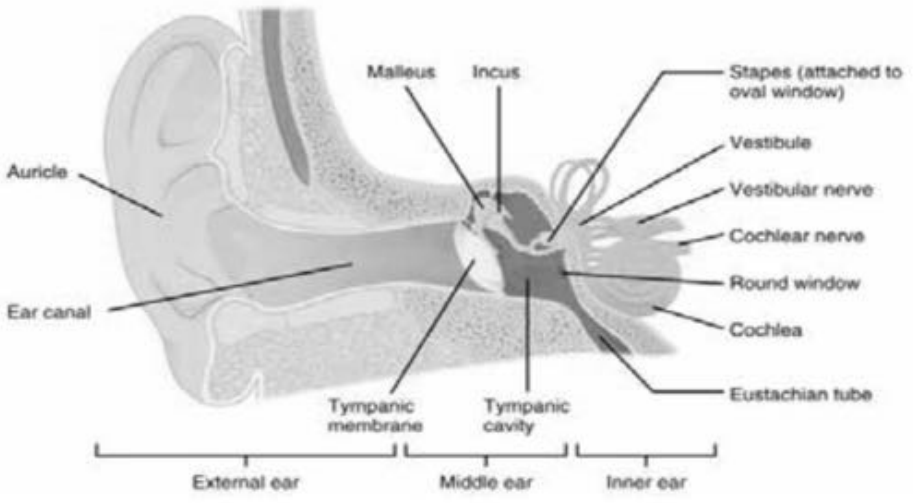
Making sure we can speak the language

23



3D model created by NIH using MRI to map labyrinth: www.vestibular.today

24

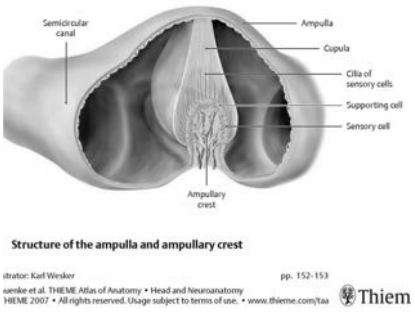


Exquisite motion detector, housed in Temporal Bone Size of Dime, Designed to work in pairs

25

Primary Sensor Units
Cupula & Macula

Semicircular canals

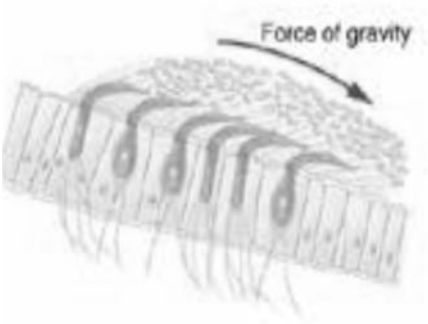


Structure of the ampulla and ampullary crest

pp. 152-153

Thiem

Utricle and Saccule



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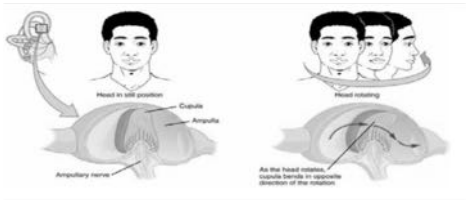
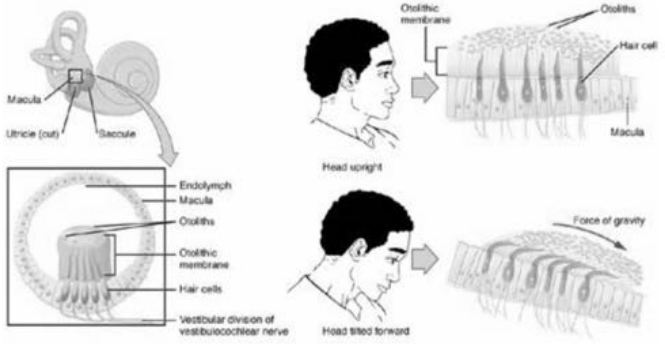
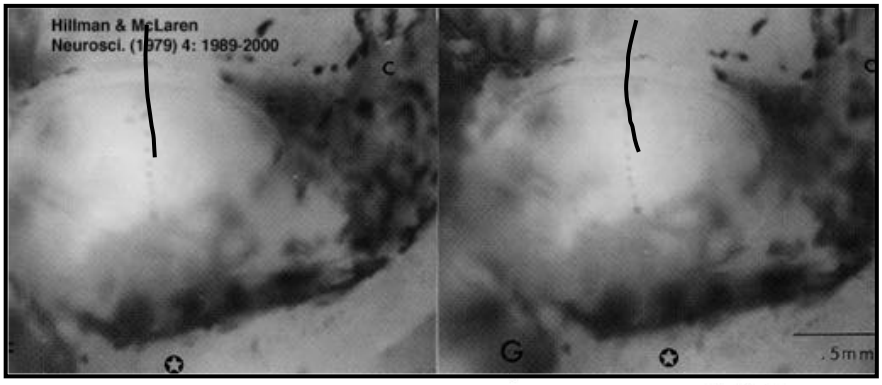
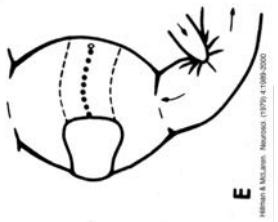




Anatomy and Physiology by OpenStax is licensed under Creative Commons Attribution License v4.0

27





Hillman & McLaren, 1979

28

Each hair cell can individually generate 2 opposing nystagmus patterns :

- Dependent on direction of hair cell bending
- AmpulloPEDAL
  - Toward
- AmpulloFUGAL
  - Away
- Excitation (more intense) or Inhibition

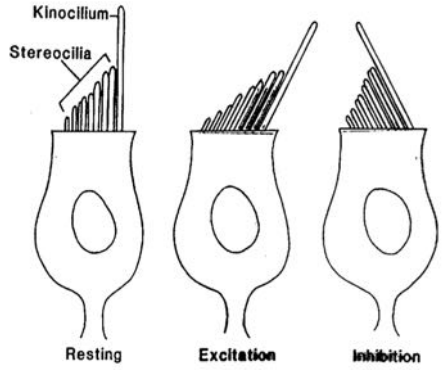
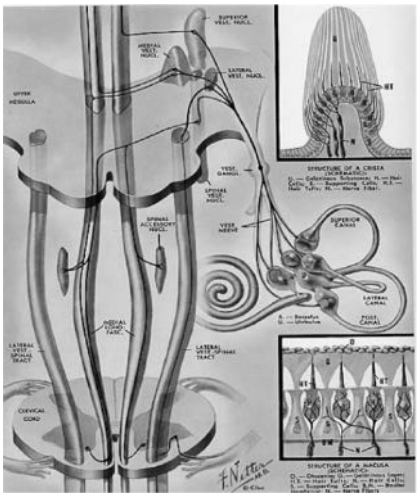
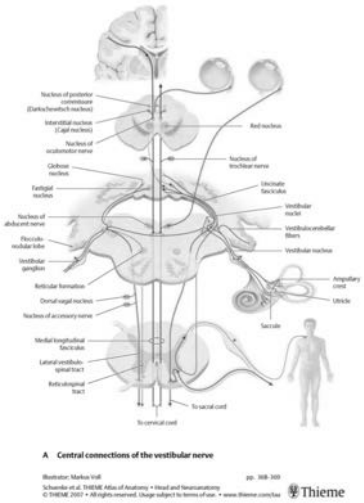


Figure 15.2. Macula of the utricle illustrating the single, large kinocilium and smaller stereocilia. Neural excitation occurs when the stereocilia are deflected toward the kinocilium. When the stereocilia are deflected away from the kinocilium, neural inhibition occurs.

29

Central Vestibular System





A Central connections of the vestibular nerve

30

Vestibular Goals

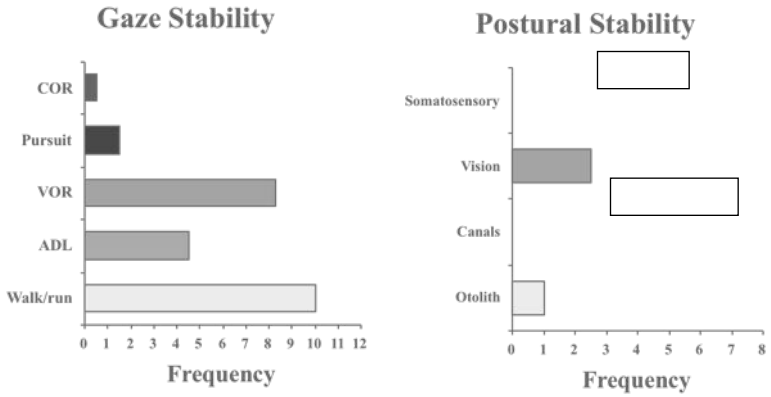
- Stabilize Vision
- Keep Balance
- Detect/process Motion

Need for speed!!!!

ADL's :

- Velocities up to 550 d/sec
- Accelerations up to 6, 000d/sec
- Frequencies 1-20hz

Only the Vestibular system detection across ranges



Source: S. Herdman, 1998

32

VESTIBULAR HEALING

What is the basis?

What is the evidence?

How do we convert that into what we do in the clinic?

33

Vestibular Rehabilitation

- Vestibular Rehabilitation is a comprehensive exercise-based approach to manage dizziness and balance disorders.
  - Historically limited medical/surgical options
  - Growing understanding of the vestibular and balance systems
  - Documented effectiveness growing from number of randomized controlled studies

34

Progression of Vestibular Rehabilitation

- Cawthorne & Cooksey 1940's
  - "Habituation" retraining
- Norre & DeWeerdt (1987)
  - habituation retraining on numerous case studies
- Descriptive Reports/Applications
  - Shumway-Cook & Horak 1990
  - Shepard/Telian 1991
    - 80-85% improvement (subjective and disability
- Herdman, 1995
  - First use of VOR adaptation exercise vs pursuit-only eye movements with only VOR adaptation group showing changes in posture, gait and perception of imbalance

35

Cawthorne MD 1945 Critical Observations

- Noted improved function/less symptoms in patient's status post surgical vestibular ablation with movement/exercise
- Described the "corrective saccade": "following sudden head turning … sometimes a fleeting flicker may be present".
- Hypothesized root cause may by end-organ in the labyrinth

36

Original Vestibular Rehabilitation Prescription (1946)

- FS Cooksey: (Cawthorne-Cooksey)
- 4 principals
  1) EDUCATION: gain patient confidence/co-operation by explaining nature of symptoms and purpose with emphasis on need to make regular and gradually increasing efforts to do those things they find stressing
  2) Anxiety must be relieved early on
  3) A rehab team member should be in charge
  4) Rehab should include physical, mental and occupationally relevant exercises planned to occupy the whole day and at the same time allow adequate periods for rest

37

Cawthorne-Cooksey Exercises

A. Eye/head mvmt, sitting (slow then fast)
B. Head/body, sitting
C. A.B. in standing

A) Eye and head movement, sitting down - first slowly, then faster:
1) Look up and down;
2) Look to the right and to the left;
3) Bring your fingers closer and farther, looking at it;
4) Move your head (slowly and then faster) to the right and to the left, with open eyes;
5) Move your head (slowly and then faster) up and down, with open eyes;
6) Repeat 4 and 5 with closed eyes.

B) Head and body movement, sitting down:
1) Place an object on the floor. Take it and bring it above your head and place it on the floor again (look at the object the whole time);
2) Shrink your shoulders and make circular movements;
3) Bend forward and take an object through the back and front of your knees.

C) Standing up exercises:
1) Repeat A and B2;
2) Sit down and stand up, sit down and stand up again;
1) Sit down and stand up; Sit down and stand up again with closed eyes;
2) Stand up, but turn to the right while standing;
3) Stand up, but turn to the left while standing;
4) Throw a small ball from one hand to the other (above the horizon level);
5) Throw a small ball from one hand to the other under your knees and alternatively.

Other activities to improve balance:
1) Climb up and downstairs (use handrail, if necessary);
2) Stand up and take sudden 90o turns (first with open eyes, then with closed eyes);
3) While walking, look to the right and to the left (as if you were reading labels in the market;
4) Practice standing on one foot (with the right foot then the left foot), first with open eyes, then with closed eyes;
5) Stand up, on a soft surface;
a) Walk on the surface to get used to it;
b) Walk on the tip of your feet first with open eyes, then with closed eyes;
c) Practice exercise 4 on a soft surface;
6) Circle around a person that is on the center that throws a large ball (which should be thrown back);

38

Igarashi 2 Stage Vestibular Ablation

- Complete recovery noted after UVL, faster in exercise group
- After second ablation (Bilateral Vestibular Loss)
  - All groups had difficulty on “beam walk” initially
  - Preoperative performance reached 62 days vs 81 days in control group
  - 8 consecutive days: 118 days Vs some >300
  - Conclusion: BVL slower, outcome influenced by exercise, exercise impacts rate of recovery

39

SHEPARD Study

- N=152 (*Prospective observational study)*
- BPPV(9%): 100% complete resolution
- BVL:
  - no change (oscillopsia, CDP, disability), subjective improvement, education & repeated practice
- CNS(8%): same improvement as UVL
  - significantly longer treatment
- Mixed (23%): 62% vs 85%
  - lower disability scores predictive of worse outcome

40

HORAK Controlled Study

- *Otolaryn Head Neck Surg 1992 &1994)*
- N=25, 18-60, PVL>6mos, randomized
- Comparison customized VR vs generic vs meds
- Significant reduced postural sway VR only
- SOLEO improved VR only
- MSQ improved VR only
- Subjective: 92% VR, 75% G, 75% med
- **Rate of falls increased for med group**
- Balance skills maintained 6 mos DC

41

Horak FB, et al: Otolaryngol Head Neck Surg 1992; 106:175-180

42

KREBS Controlled Study

- Krebs OHNS (1993) Bilateral Vestibular tx
- N=8, mean 64 (7 females, 1 male),
- Double blind VR vs strengthening x8wks (cross-over)
- Findings: 8% faster gait, 17% decreased double stance support, 10% greater moment arm for VR group only
- 1% with control group only
- All groups improved subjectively (JDH)
- VR cont to improve with home exercise

43

SHEPARD Controlled Study

- Shepard Otolary head neck (1995)
- Success with customized versus generic
- SRS: 64% Vs 85% customized
- DRS: only 50% no-min disability Vs 75%
- Objective: spontaneous, chair assymetries, MSQ, static/dynamic balance measures
- BVL 50% sign improvement locomotion variables versus control

44

Habituation – Evidence of Treatment Efficacy

- Improved symptoms scores post-treatment in patients with chronic vestibular deficits (n = 152)
- 0 = complete symptom resolution
- 1 = marked improvement / mild symptoms
- 2 = mild improvement / persistent symptoms
- 3 = no improvement
- 4 = worse

Shepard NT and Telian SA. Otalaryngol Head Neck Surg 1995; 112:173-182

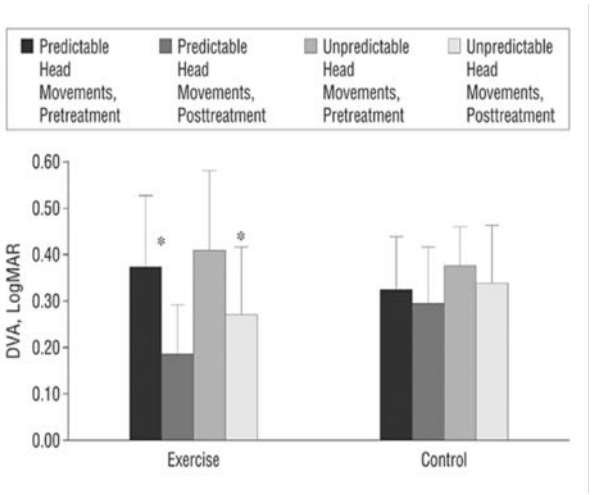
45

HERDMAN Controlled Study

- Herdman AAOHNS (1995)
- Acute Acoustic Neuroma study N=21
- Post op day 3-6 acute recovery following UVL
- 2 exercise groups(20min)
  - Control: smooth pursuit and walking ex
  - Experimental: VORX1 standing and sitting
- Postop day 6:
  - 80% Vs 57% romberg, 40% Vs 100% abnormal gait, 50% Vs 100% ataxia during gait with head turns, 73% Vs 29% normal VOR at slow speeds, gaze-evoked same

46

DVA only improved in group with gaze stability exercises



Herdman and Clendaniel: Otolaryngol Head Neck Surg 1995; 113:77-87

47

Behavioral Measures of Dynamic Vestibular Compensation Vestibulo-Ocular

- Compared with control group (no vestibular rehabilitation or placebo exercises)
- DVA improves (Herdman 03, 07; Schubert 08)
  - Appears due to increased VOR gain and increased recruitment of compensatory saccades
- VOR Gain (eye velocity/head velocity) to ispi and contra-lesional slow rotations becomes symmetric (Szturm 94)
  - Presumed restoration of tonic vestibular firing at nuclei

48

What Does the Cochrane say?

- Cochrane Systematic Review Unilateral peripheral Vestibular Disorders in 2015 McDonnell & Hillier

"There is moderate to strong evidence that vestibular rehabilitation is a safe, effective management for unilateral peripheral vestibular dysfunction, based on a number of high quality randomized controlled trials."

49

Latest Research

50

Adaptation – Mechanism of Recovery & Change

- Head motion coupled with images moving off fovea is the most powerful error signal to drive VOR adaptation
- Other error signals include visual-vestibular conflict in strobe light, after-image tracking
- Signals for VSR?

51

Biomarker for Vestibular Loss & Recovery

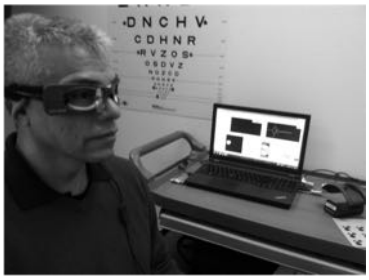
- The Corrective Saccade

52

CONTINUED

Vestibular Head Impulse Testing (vHIT)



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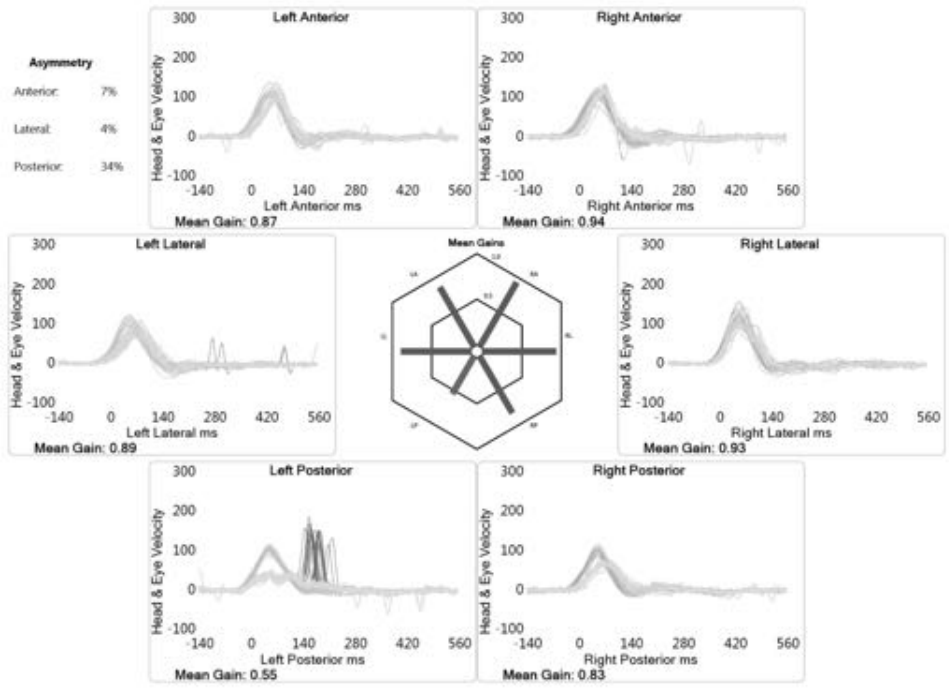

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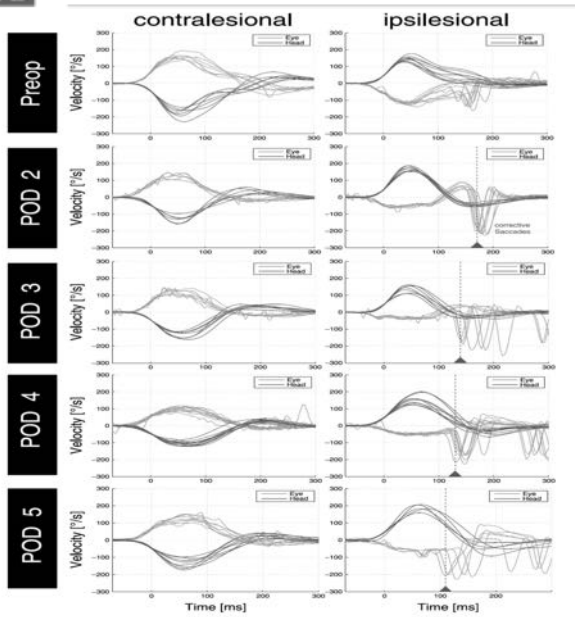


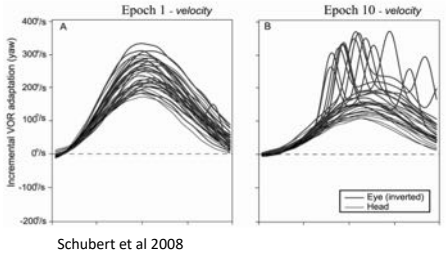
Mantokoudis 2014

3 impulses were performed preoperatively and postoperatively (POD 2–5) on the ipsilateral and contralesional s
idicate head velocity, *grey traces* eye velocity. *Black dotted lines* mark the time of the first appearance of a cor

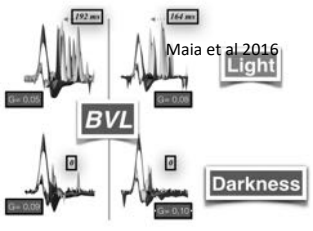
55

Vestibular and Visual Systems are Linked

- The inter-dependency between vestibular and visual afference enables a means for vestibular compensation
  - Unique type of saccade is substituted for a deficient vestibulo-ocular reflex (VOR)
  - The latency and amplitude of these unique saccade are dependent on light



Schubert et al 2008



Maia et al 2016

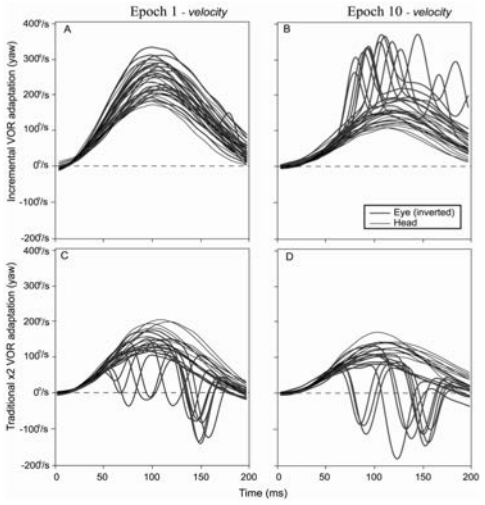
56

CONTINUED

Adaptation – Mechanism of Recovery & Change

Is adaptation to head impulse possible?

- Yes



Schubert et al 2008

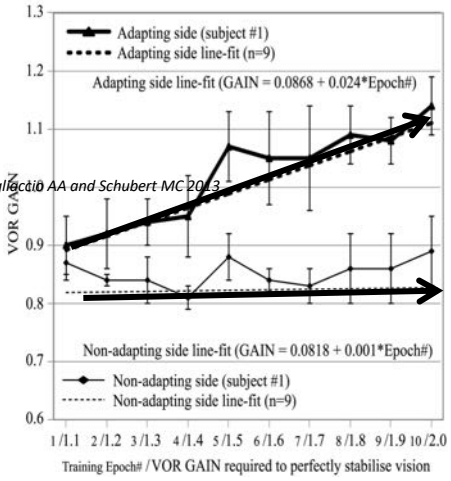
57

CONTINUED

Adaptation – Mechanism of Recovery & Change

Is unilateral VOR adaptation possible?

- Yes



Migliaccio AA and Schubert MC 2013

Pilot study of a new rehabilitation tool: improved unilateral short-term adaptation of the human angular vestibulo-ocular reflex. Migliaccio AA, Schubert MC. Otol Neurotol. 2014 Dec;35(10):e310-6. PMID: 25122595

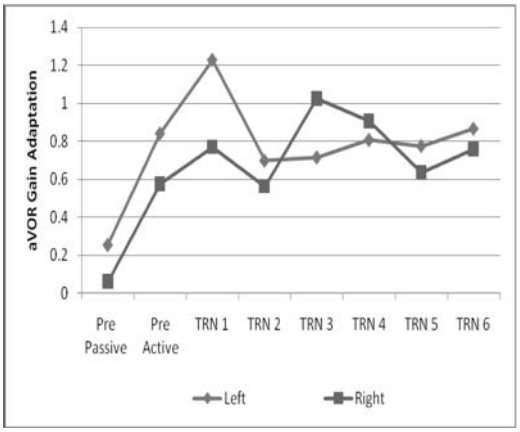
58

CONTINUED

Adaptation – Mechanism of Recovery & Change

Can patients with BVH have VOR gain Adaptation?

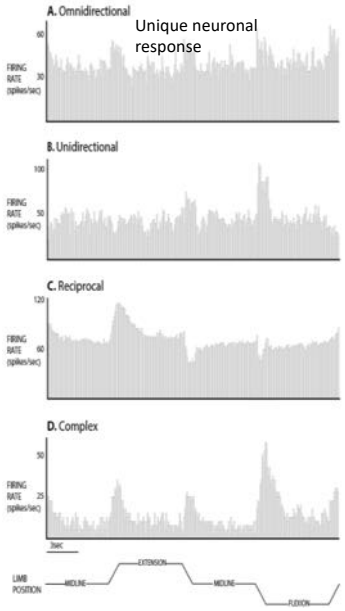
- Yes



59

The Vestibular and Somatosensory Senses are Linked

- 41% of vestibular neurons (cat) are modulated by hindlimb stimulation (cat) (McCall AA et al. 2016)
- In human, limb position, weight distribution, and ground compliance (standing) alter vestibulospinal reflexes (Grasso et al. 2011; Marsden et al. 2002; Welgampola and Colebatch 2001)



60

I was at the ATM the other day, and an elderly lady approached and asked me to help check her balance.

So I Pushed Her.

61

Postural Learning

- **Postural control** requires challenge
- Learning correlated with **degree of postural instability**
- **Greater initial risk for falling**, greater percent reduction in sway amplitudes from training
- **Sway can be reduced** with practice
- Brandt, 1989

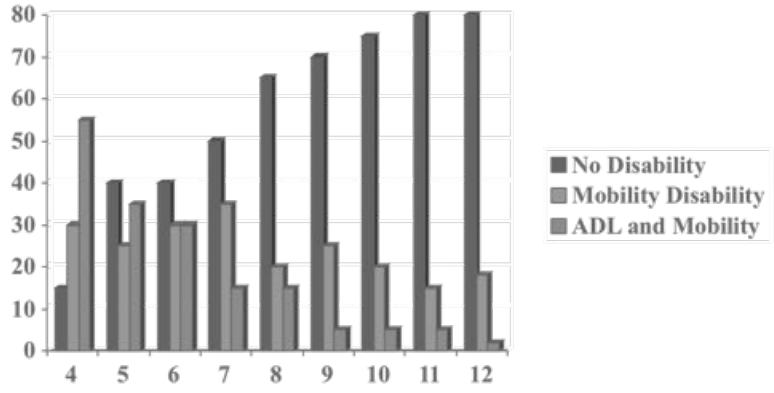
62

Guralnik Disability Study

- Prospective Study,
  - N=1122, >71, not disabled (stairs, walk ½ mi)
- Tested on balance skills (0-4)
  - Standing BOS(HTEO 10sec), 8' walk(<3sec)
  - Sit to Stand 5X (<11 sec),
  - Scores ranged from 3-12
- 4 years later follow-up
- Balance function highly predictive of subsequent disability
  - Those with the lowest scores 4-5X more likely to have disability

63

Summary of Performance Scores



64

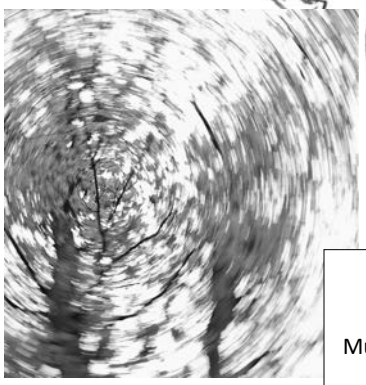
Clinical Bedside Vestibular Examination

The foundation of effective Exercise Prescription

65

Spectrum of Dizziness

minor worry to complete incapacitation



Must know Why?

66

CONTINUED

The "Dizzy" History

- Far most important part of exam
  - Extremely difficult for patient
- History of Motion Sickness, Motion tolerance
- Important to note:
  - Onset/Circumstance
  - Quality/intensity
  - Tempo: Temporal Pattern
  - Associated/Traveling Symptoms
  - Contributing Factors

Must Focus on the Intense more acute

67

CONTINUED

"Dizziness"

International Classification of Vestibular Disorders ICVD in Journal of Vestibular Research 2009 (19): 1-13

- Non-specific term, needs to be defined
- Vertigo: any sensation of movement when NOT occurring
  - Pathophysiology: central or peripheral insult that caused asymmetrical neural activity and asymmetry occurred rapidly
  - Labyrinth through pons and posterior cerebellum
  - Unlikely: lesion above pons or anterior circulation i.e. carotid arteries
    - Imbalance/lightheadedness
- Unsteadiness: general or actual ataxia and possible falls
  - Labyrinthine disorder without vertigo
    - Slowly developing lesion e.g. vestibular schwannoma, hereditary vestibular degeneration
    - Bilateral insult e.g. ototoxic drugs
- Dizziness: anything that is NOT vertigo or unsteadiness
  - Lightheadedness, giddiness

68

CONTINUED

Tempo: Main framework

- If patient chronically dizzy, find out what is bringing them in NOW.

- Most intense dizziness/vertigo:
  - Seconds/minutes positionally-provoked: BPPV or uncompensated UVL
  - Minutes to hours spontaneously provoked Migraine/Meniers attacks
  - Hours to Days: Vestibular (UVL) Crisis such as Neuritis or inner ear infections

69

CONTINUED

Tempo	Circumstance	Auditory	Differential
Episodic: Seconds to min	Head Motionn(HM) & Head Position (HP) Provoked	Normal	**BPPV**, uncompensated neuritis
Episodic: Sec to Min	Spontaneous	Normal, nonspecific fluctuations	**Migraine**, r/o TIA, anxiety disorders,
Episodic: 20 Min to hours (<24)	Spontaneous	Documented Fluctuant and Progressive	**Meniere's** disease
Days (1-2) (24-48 hours)	Spontaneous, Increase with HM/HP	Normal	**Vestibular Neuritis** (crisis)
Days	Spontaneous Increases with HM/HP	Sudden associated loss	**Labyrinthitis,** PICA or AICA stroke

70

Tempo	Circumstance	Auditory	Differential
Continuous	Possibly exacerbated by HM/HP	Normal	**Central**, **anxiety/psychiatric**
Continuous imbalance w/ some sec/min fluctuations	Distinct exacerbation with pressure or sound	Autophony (distorted hearing sensitivity)	**Superior Canal dehiscence Syndrome (SCDS)**
Continuous	ROCKING, relieved when in motion, ONSET with unusual travel	Normal	**Mal de Debarquement Syndrome (MdDS)**
Continuous w/ some waxing waning	SEVERE Visual motion sensitivity w/ some HM//HP	Normal	**Persistent Postural Perceptual Dizziness (3PD)**

71

Neurologic Red Flags: "Neurologic Travelors" or the "D's"

- 5 Brainstem D's
  - Dysarthria
  - Diplopia (visual disturbance)
  - Dysphagia
  - Drop (LOC) to decreased consciousness
  - Dizziness
  - (Diaphoresis-6th?)
- Decreased sensation
  - Paresthesias/numbness (perioral numbness w/ VBI)
- Decreased Muscle strength
  - Non-dermatomal (alarming/sudden loss with VBI)
- Declined Fine motor skills

72

Vestibular Pathology

- Receptor Level (end organ disease)
  - Mechanical disruption (Benign Positional Vertigo)
  - Fluid pressure/membrane rupture (Menier's dx)
  - Bilateral Vestibular Loss (BVL)(Ototoxicity, autoimmune, genetic)
  - Unilateral Vestibular Loss (UVL) (Vestibular Neuritis, Acoustic Neuroma, or Migraine)
  - **Abnormal pressure communication** (Superior Canal Dehiscence, Endolymphatic fistula)
- Brainstem central integration
  - Stroke, Demylinating dx (MS), Migraine
- Perceptual
  - TBI, drug effects, anxiety/psychological, Migraine

73

Head Impulse Testing (HIT)

- **Bedside Test to detect loss of vestibular or inner ear function**
- Check Neck
- Perform slow/smooth initially
- Hold patient's head firmly and then with quick impulse turn the head <10 degrees
- Observe any even momentary loss of visual fixation (CORRECTIVE SACCADE)
  - Suggests declined inner ear capacity to that side
- Can be unilateral or bilateral

74

CONTINUED

Finding Corrective Saccades

75

CONTINUED

After Headshake Nystagmus

(46% Sensitive 75% specific, good test incomplete compensation)

- Patient sitting at end of exam table
- Pitch patient's head down 30 degrees, and have patient close his/her eyes.
- Quickly "shake" patient's head side to side 20 times, stop abruptly and without allowing their head to change, observe stability of their eyes or presence of nystagmus, if more than >3 beats:
  - Left beating: right paretic vestibular loss
  - Right beating: left paretic vestibular loss

76

Head Shake Nystagmus (HSN)

- N=235 patient's with acute peripheral vestibular disease and 1 mo f/u
  - (Kim MB et al Otology & Neurotol 2012)
  - Neuritis (VN), Meniere's disease(MD), BPPV
- Head Shake Nystagmus noted in 37%
  - 100% Vestibular Neuritis
    - 100% initially contra-lesional beating
    - strongly correlated to severity of initial loss
  - 69% Meniere's Disease,
  - 22% BPV
    - ONLY with LC BPPV
    - Beats to good side (**paretic nystagmus!!!**)
- HSN that is vertical (down/up: Perverted Nystagmus) to either horizontal or vertical testing is CENTRAL FINDING
- Helpful at picking up Age related critical vestibular hypofunction and fall risk.

77

Age-Related Critical Loss of Vestibular Function

- *Ekvall Hansson E, Magnusson M, 2013*
  - Prospective 1 yr study, 55 patients 65-90
  - Head shake, vibration sense, balance, DHI, CDP
- Abn Head shake 24/55 (44%), with substantially increased risk for falls (OR 3.4, CI 1.09-10.59, significant at .05 level)
- 13/21 (61%)who fell and 6/6 (100%) who fell 3+ times had vestibular asymmetry
- No other measure could predict falls
- Simple bedside test of vestibular asymmetry can help screen for falls in elderly

78

Dynamic Visual Acuity Testing

www.i-see.org

- Snellen or ETDRS LogMAR Visual Acuity Chart
- Read lowest line with head stationary
  - Normal is <3 line deterioration
- Tilt head 30 degrees and move head at 2 hz head shake (Metronome 120/cycle or 240bpm each side) and ask patient to read lowest line again
- Generally:
  - Loss of >3 lines: Unilateral Vestibular loss
  - Loss of >5 lines: Bilateral Vestibular Loss
- Evidence for Gaze Stabilization Prescriptions

79

Decline in Vestibular Function with age

Agrawal Y et al (2012) Otol Neurotol 33(5): 832-839

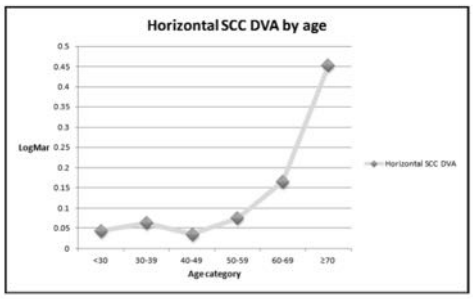


Figure 1.
Head thrust dynamic visual acuity in the horizontal semicircular canal plane by age. Overall differences are statistically significant ($p<0.0001$). The better one's visual acuity, the lower one's LogMAR score. SCC: semicircular canal; DVA: dynamic visual acuity.

80

Motion Sensitivity

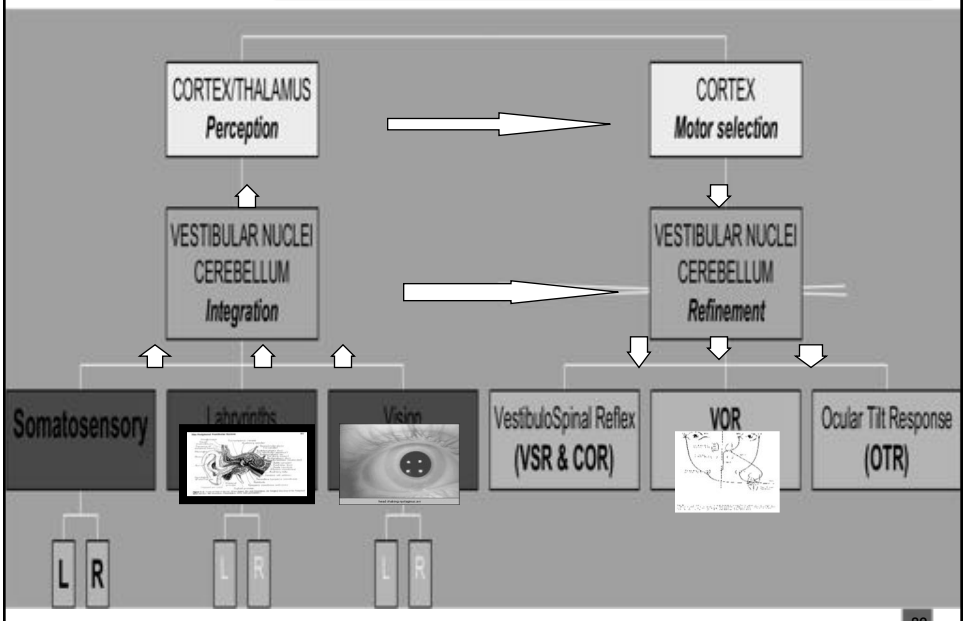
- Basis for habituation prescription

POSITION	NYSTAGMUS	INTENSITY	DURATION	SCORE
1.Sitting to Supine				
2. Supine Roll Left				
3. Roll Right				
4. Supine to Sit				
5. Left Dix-Hallpike/Brandt Daroff				
6. Return to sitting				
7. Right Dix-Hallpike/Brandt Daroff				
8. Return to sitting				
9. Stand/sit Nose to Left foot/knee				
10. Return to stand/sit				
11. Stand/Sit Nose to Right foot/knee				
12. Return to stand/sit				
13. Standing 5 Head rotations				
14. Standing 5 Head tilts				
15. Standing pivot (360) turn to right				
16. Standing pivot (360) turn to left				
Motion Sensitivity Quotient:		0(no sx)-5(severe)	5-10 sec=1	
			11-30=2	
			>31=3	
#positions X score /2048			**TOTAL:**	

Severity: ____none ____Trace (1-3%)____Mild (4-14%)____Moderate(15-30%)____Severe (>31%)

81

Respecting BALANCE SYSTEM DYNAMICS



82

Sensory Balance Testing:

C.linical T.est for S.ensory I.ntegration in B.alance (CTSIB)

- 1: Stable ground/eyes open
  - Redundant senses available
- 2: Stable ground/eyes closed
  - Somatosensory system stressed (Romberg)
- 3: Stable ground/vision inaccurate (dome)
- 4: Foam/tiltboard ground/ eyes open
  - Vision stressed & increased motoric demands
- 5: Foam/tiltboard ground/eyes closed
  - Vestibular system stressed & increased motoric demands
- 6: Foam/tiltboard ground/vision inaccurate
- If use modified CTSIB, term all as Romberg variants
  - EO (eyes open), EC(eyes closed)
  - EOF (eyes open foam), ECF (eyes closed foam)

83

SENSORY BALANCE TESTING:

- Romberg TESTING
  - Eyes Open/Closed
- Clinical Test For Sensory Interaction on Balance (CTSIB), modified

Condition 1: Eyes open, Firm Surface

Condition 2: Eyes closed, Firm Surface (Somatosensory Environment)

Condition 4: Eyes open, Foam Surface (Visual Environment)

Condition 5: Eyes closed, Foam Surface (Vestibular Environment)

84

85

Assessing full CTSIB

86

Motoric Balance Testing

- Single Leg capacity
- Heel-Toe capacity
- Normed-referenced scales available

87

Normal Findings with Single Leg Stance

(Bohannon, 1984)

Decade	Eyes Open/Closed
20-29	30secs/28.8secs. , +-2.3 *30/ 26-30*
30-39	30secs/27.8secs, +-5.0 *30/22-30*
40-49	29.7secs,+-1.3/24.2secs,+-8.4 *28-30/15-30*
50-59	29.4secs,+-2.9/21.0secs,+-9/.5 *26-30/11-30*
60-69	22.5secs,+-8.6/10.2secs,+-8.6 *14-30/2-18*
70-79	14.2secs,+-9.3/4.3secs,+-3.0 *5-23/1-7*
OVERALL: 30 seconds is normal <5 seconds is Abnormal	All subjects could perform Romberg (open & closed) 30 sec. 89% community adults can stand >10 sec (Rossiter 1995)

88

GAIT or Walking TESTING

- Standard analysis
  - Cadence speed
  - Gait velocity
  - Gait quality
- Tandem walking and eyes closed
- Walking while turning head horizontally
- Walking while tilting head up or down
- Maneuvering tasks
  - Abrupt stops, pivot turns, etc.
  - At what cadence speed

89

VESTIBULAR Gait

- Wide BOS, Maneuvering “en bloc”, Ataxic to head motions
  - Kerber KA et al 1998
- Inconsistent occasional veering or staggering
- Acutely pulled to side of lesion
  - Stronger veering if eyes closed tasking
- If bilateral, ataxic but not with same quality/intensity of cerebellar ataxia
- Krebs et al 2002
  - @self selected speed BOS normal but decreased velocity
  - @ 120s/min increased gait variability, decreased gait speed, increased BOS
- Slower gait documented in pts with vestibular deficits
  - *Whitney SL 1997 Phys Therapy*
    - Marchetti G Whitney S et al 2008 PT journal
    - Decreased speed, Decreased step length, Increased double support, Increased step width, Increased stance variability
    - DGI shown to be reflected of vestibular gait
    - Increased variability, decreased cadence

90

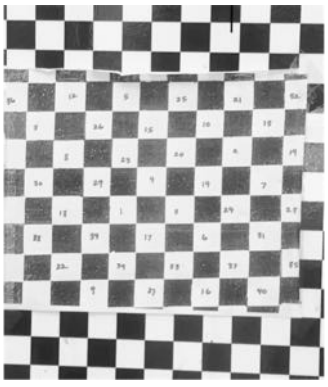
Documenting Fall Risk: Critical

(RIC rehabilitation measures database)

- Recurrent faller= >2 in 6-12 months
- ABC= <67% (<80% impaired community access)
- Functional Gait Assessment= <23
  - Wrisley DM PTJ 2010, MCID 4 points (Beninato M 2014 PTJ)
- 5X sit to stand (>13.6 s increased disability/morbidity)
  - 65-74 yo 14.7 sec
  - 75-84 yo 15.7 sec
  - 85+ yo 16.3 sec (Whitney SL et al PTJ 2005; Guralnik 2000)
- Functional Reach (Duncan , 1992)
  - <10" low risk, 6-10" Moderate risk, 1-6" High Fall Risk (4X)
  - Unwilling or unable to reach=8X more likely to fall
- Abnormal CTSIB= sensory specific
- Berg (Berg et al 1992) = <45 (Lajoie, 2004)

91

Treatment for Vestibular Hypofunction



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92

Unilateral Vestibular Loss:

Clinical Findings ID need for rehab

- Evidence of poor physiologic compensation/healing
  - Symptomatic, strong after head shake nystagmus
  - Symptomatic and marked direction-fixed positional nystagmus
    - Abnormal Motion Sensitivity Testing
  - Abnormal VOR: +Head thrust
    - Can be bilateral initially with severe/acute, gross overt vs more subtle and moving to covert
- Evidence of poor functional compensation/healing
  - Abnormal DVA: >2 line loss, symptomatic
  - Abnormal Gait: en bloc, slowed velocity, ataxic to head motions
    - Often fall risk per standardized testing e.g. FGA
  - Abnormal CTSIB: abnormal sway with specific deficits 5/6
- Pursuit tracking and saccades normal for age and all other central tests

93

Bilateral Vestibular Loss: Clinical Findings

- Usually No nystagmus
- Abnormal VOR: +Head thrust bilateral, often most marked at slow speeds
- Abnormal DVA: >5-6 line loss, grossly unstable during testing, marked subjective c/o visual blurring
  - Well compensated: depending on sparring, often 3-5 line loss
- Abnormal Gait: assistance/AD needed , slowed velocity, grossly ataxic to head motions
  - Well compensated: depends on co-morbidities and sparring but often no AD, resolved ataxia with head motions, normalized velocity, no fall risk per DGI/FGA
- Abnormal CTSIB: abnormal sway or falls in multiple conditions initially
  - Well compensated: resolved falls except persistent PROFOUND “free falls” on 5/6 expected
- Pursuit tracking and saccades normal for age

94

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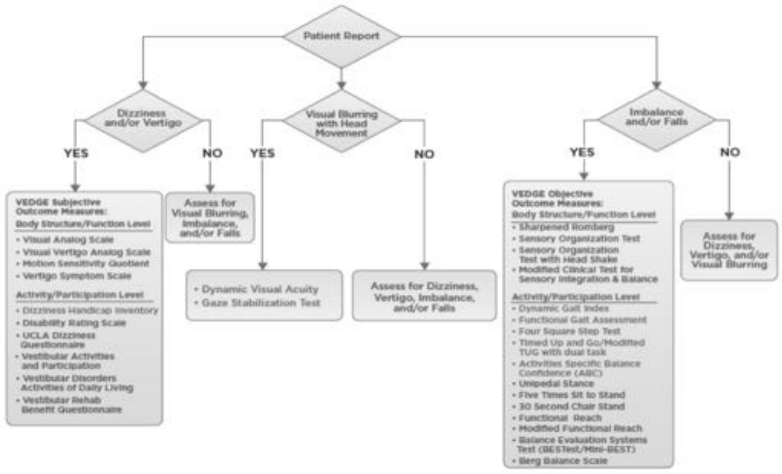
ACADEMY OF NEUROLOGIC PHYSICAL THERAPY

APTA'S EVIDENCE-BASED CLINICAL PRACTICE GUIDELINE FOR PERIPHERAL VESTIBULAR HYPOFUNCTION



Based on Centre for Evidence Based Medicine website: http://www.cebm.net/oxford-centre-evidence-based-medicine-levels-evidence-march-2009/

95

CONTINUED

ACADEMY OF NEUROLOGIC PHYSICAL THERAPY

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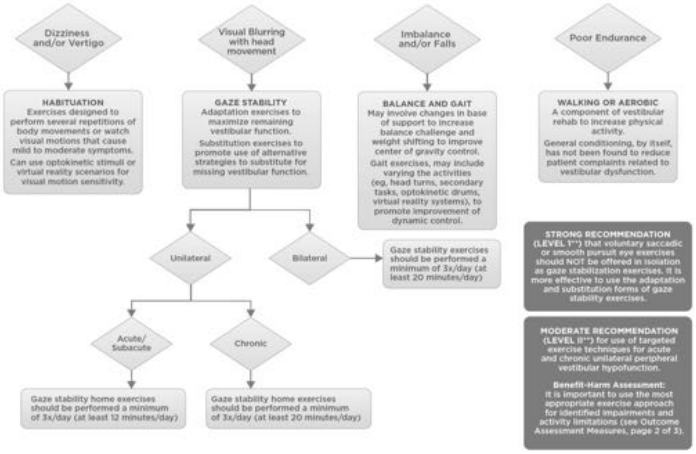


Based on Centre for Evidence Based Medicine website: http://www.cebm.net/oxford-centre-evidence-based-medicine-levels-evidence-march-2009/

96

GAZE STABILIZATION EXERCISES

Adaptation & Substitution Exercises

Foster alternative pathways to "get the job done" i.e. faster & more efficient compensatory saccades, waken more anticipatory systems, force adaptation of spared function, compensate for permanent losses with sensory substitution

97

INDICATIONS FOR GAZE STABILIZATION

Prescription RX

- Evidence of Unilateral or Bilateral Vestibular Loss
  - Primary Exercise for Inner Ear Infections (neuritis), Acoustic Neuroma, stable Meniere's disease
- Subjective c/o Blurry Vision and/or intolerance to repetitive head motions
- Abnormalities on DVA testing
  - Track DVA changes as evidence of improvement

98

ADAPTATION EXERCISES: Gaze Stabilization Drills

- *Exercise prescription of long exposure (1-2min.) of one distinct motion compared to habituation*
- Rationale: Facilitates the healing process the central nervous system undergoes in the presence of a partial vestibular loss.
- Neurophysiologic adaptation of the gain (sensitivity) of vestibular nuclei and the interconnections with the cerebellum
- Head/eye motion are mandatory
- "VORx1" and "VORx2"

99

Vestibular Adaptation Exercises: VOR X1

- Start in standing if possible 3-5' & arms distance
  - Sitting if too unstable/poor quality
  - Progress to standing with narrowing feet
  - Standing on cushions
  - Walking esp with convergence/divergence demands
- Focus point @ eye level
- Target size should be small enough to be challenging but so you can see it clearly (larger size is easier if necessary).
- Start with single target, progress to full field
- If px correctly, work on all goals of vestibular function: gaze stable, posture stable, motion integration

100

Vestibular Adaptation Exercises: VOR X1

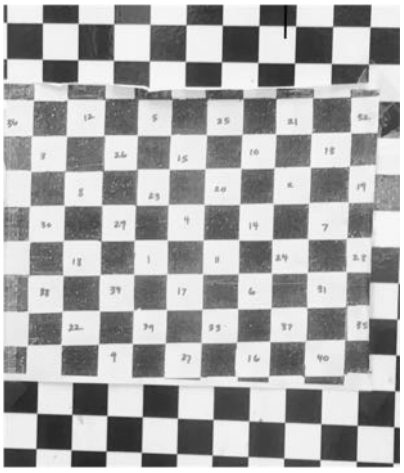
- Instructions: "While staring at focus point, rotate your head side to side, slowly at first to keep the object clear, then gradually go as quickly as possible while still keeping the word or letter in focus"
  - The letter must stay in focus.
  - Repeat vertically
- Initial Ideal dose:
  - 1-2 minutes horizontal/vertical near & far, 3-5 daily
- Work for a goal of minimum of 20 minutes
- Dr. Herdman protocols often advanced to close to 40!!!

101

Gaze Stabilization: VORx1

102

VORx1 Progressions



103

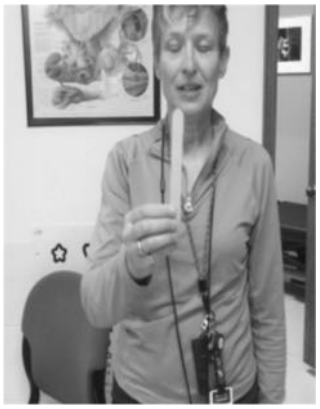
Gaze Stabilization: VOR x2)

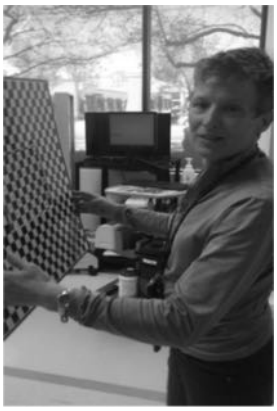
Moving Head and Object in Opposite Directions

- Start in sitting, progress to standing, standing with narrowing feet to walking
- Focus point @ eye level, target size should be small enough to be challenging but so you can see it clearly (larger size is easier if necessary).
  - Start with single target held at arms length, progress to holding a full field (checkerboard).
- Instructions: "While staring at focus point, rotate your head side to side, slowly at first to keep the object clear, at the same time moving the target in the OPPOSITE directions, gradually go faster but while still keeping the word or letter in focus."
  - The letter must stay in focus. Repeat vertically.
- Continue for 1-2 minutes/ 3-5 daily.

104

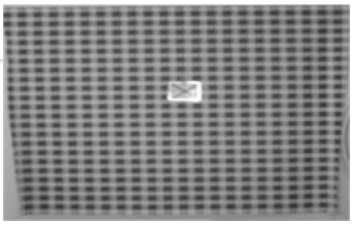
Gaze Stabilization: VORx2





105

Gaze Stabilization Progression



1. Sitting, VORX1 far foveal, 1 min H&V, 3-5X
   - TOTAL: 6-10 min
2. Standing, VOR X1 near/far foveal, 1-2 min H&V, 3-5X
   - TOTAL: 12-20 min
3. Standing (narrowing feet), VOR X1 add full/busy target plus foveal, Near/far, 1-2min H&V, 3-5X/day
   - TOTAL: 24-40 minutes (maximal dose)
4. Sitting VORX2 H/V foveal 1 min each, 3-5X/day, plus standing VORX1 near/far H/V 3-5X/day.
   - TOTAL: 24-40 minutes
5. VORX1 near/far H/V while walking and VORx2 3-5X/day standing
   - TOTAL: 24-40 minutes

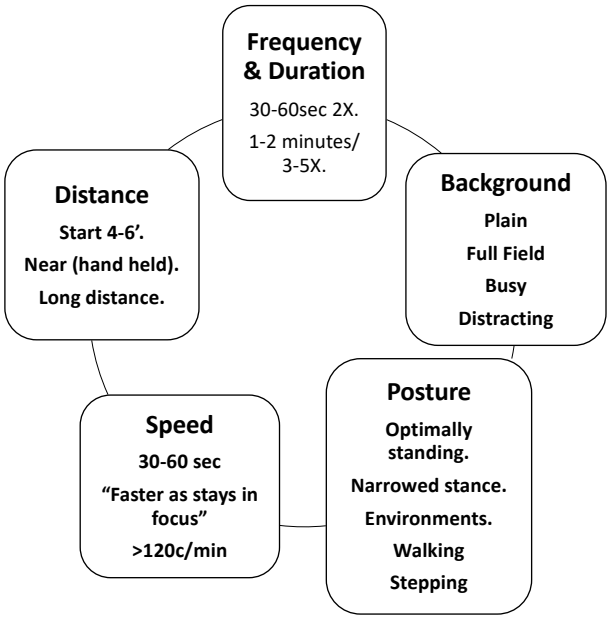
106

Gaze Stabilization Generalizations

- Try to start in standing and progress to dynamic balance challenges and walking as able
- Start with minimal stimulation at 4-6'
  - Small enough to challenge focus (cards, letters)
  - As able vary distances and speeds
- If using a metronome: may need to start 30-60 c/min (.25-.5 hz) per head turn progressing to above 240 c/minute (2 hz) as able
- Increase to busy visual backgrounds (full field vs fovea)
  - Checkerboards, etc.
- Educate patient on expectations: i.e. they may be dizzy
- Add in convergence demands as able (Walking in toward and away)
- Don't forget the neck

107

Progressing VORX1 and X2



108

OPTIMIZING VOR ADAPTATION

- Track progress with DVA changes
- Watch for under/over stimulation with VAS or SRS before and after
  - Guideline to be recovered by 20 minutes
- Targets
  - Don't make too easy, are they attending
  - Quality of motion and attention to visual focus capacity (some PTs don't understand "blurry")
- Remember to somehow change their exercise on each follow-up
  - Are they in optimal balance challenge?
  - Frequency, Duration and speed and distance
  - Background
    - Beyond X on wall
    - Tennis ball with letters or Marsden ball from ceiling
    - X on moving background TV screen

109

GAZE Substitution Exercises

- Process by which the gaze stability system recovers when there is a permanent and/more complete loss to the vestibular/balance system
  - Bilateral vestibular loss and some Unilateral
  - Severe Unilateral (poor DVA)
- Facilitate alternate pathways to "get the job done"
  - Provide exposure to errors to stimulate reorganization
  - Smooth pursuit
  - Saccades
  - Anticipatory systems
  - Cervical ocular reflex
- Gaze stabilization can be achieved thru other alternative eye motions

110

GAZE Substitution Exercises

- Active eye-head movements between targets (**GAZE SHIFTING for Saccade/VOR facilitation**)
  - look quickly between targets focusing first with eyes then with a head motion
- REMEMBER targets (**Central Preprogramming Facilitation**)
  - Stare at target, close eyes imagining focus point and turn your head slightly trying to maintain target
- Slow VORx1/Enhancing COR (**Cervical Ocular Reflex**)
  - turn head slowly while trying to focus on object

111

Gaze SHIFTING

- Tape two targets ("X" and "Y" horizontally) at eye level
  - sitting (progress to standing as able)
  - Two objects are 3-4 feet apart when you look one object you are able to see and move your eyes to the other without having to move your head
- Sit 10' away (progress to holding cards in hands)
- Instructions: Look directly at the "X" with your head lined- up and facing the "X", now without moving your head look directly at the "Y" with your eyes first then turn your head so your nose points directly at the "Y"as well.
- Keep repeating
  - Eyes always move first
  - Goal is to keep the letters in focus especially when your head is moving.
  - Gradually make faster and faster head motions.
  - 1-2 minutes. Rest briefly. Repeat vertically.

112

Gaze Stabilization: Gaze Shifting

113

Remembered Targets (Imaginary)

- In sitting, Tape an “X” on the wall 1-2 feet in front of you and look at it.
- Close your eyes and turn your head slightly, remembering the exact location of the “X”.
- When you stop moving your head, immediately open your eyes and check to see if you are still looking at the “X”. I f you had to move your eyes, you weren't’t looking at the “x” anymore.
- Repeat the opposite direction
- Practice for 1 minute vary the speed and size of the head motion you make.
- Practice with target in motion as able

114

Gaze Stabilization: Remembered Targets

115

VOR X1 for Fostering Substitution>adaptation

- Focus point @ eye level, target size should be small enough to be challenging but so you can see it clearly (larger size is easier if necessary).
- MOVE at very SLOW speeds and work to "get the job done"
  - Have actually read or tell numbers
  - May be some jumping… minimize saccades as observe them
- Instructions: "While staring at focus point, rotate your head side to side, SLOWLY trying to keep the object word or letter in focus".
    - The letter must stay in focus.
    - Repeat vertically.
- Continue for 1-2 minutes/ 3-5 daily.
- Ideally work them from total of 20 minutes of sustained head motions to close to 40!!!

116

Gaze Stabilization Spectrum

VORx2	VORx1	Gaze Shifting	Remember Targets
Forcing higher adaptation	Adaptation WORK HORSE Ex	Adaption/Substitution Exercise	
ID: ABN DVA, progression for VORx1, sparred vestibular function, higher level complaints i.e. when jogging, running, sports	Beginning exercise for many diagnoses/impairments	Used often in conjunction with VORx1	Substitution, based on position error, feed forward systems
	ID: ABN DVA, c/o blurred vision during head motions	ID: ABN DVA losses, co difficulty seeing clearly with larger amplitude motions i.e. drive/shop	ID: ABN more severe DVA losses, more severe vestibular loss i.e. Bilateral Vestibular Losses

117

Progression and Px Guidelines

- Watch for under/over stimulation with VAS or SRS before and after
  - Guideline to be recovered by 20 minutes
- Are they in optimal balance challenge?
- Quality of motion and attention to visual focus capacity (some PTs don't understand "blurry")
- Beyond X on wall
  - Numbered poster 1-40
  - Checker boards Saccade handheld poster
  - X on TV screen (busy background)
  - Reading a book

118

The Fine Art of CUSTOMIZED PROGRESSIVE HABITUATION

DO YOU REMEMBER WHEN…..

"Spinning around, getting dizzy, and falling down was cause for giggles?"

119

120

Habituation Basics

- Definition *"A reduction in pathologic response to a specific movement brought about by repeated exposure to the provocative stimulus"*
- Prescribe based on
  - Analysis of dizziness from the Motion Sensitivity Test
  - Dizziness Handicap Inventory
  - Performance/difficulties on Functional Gait/Dynamic Gait Index

121

Habituation Basics

- Choose no more than 3 motions
  - evidence of habituation
  - Sufficient Intensity (speed and range of movement)
  - no greater than 2-3/5 subjective severity
  - DEMAND sufficient rest/restabilization between repetitions: dizziness + 30 seconds
- Repetitions: 3-5X, 2-3 times daily
- Symptoms should return to baseline within 20 minutes

122

BRANDT-DAROFF EXERCISE

123

Facilitating Balance and Postural Control

124

PRINCIPLES

- Educate
  - High risk ,avoidance, modifications, role-play
- Advance through hierarchical progressions
- Compensate or substitute for system impairments which are permanent
- Balance is responsive to demands of TASK AND ENVIRONMENT
- When sensory processing deficit is identified: STRUCTURE ENVIRONMENT TO FORCE-USE THAT SYSTEM
- When a motor skill (ROM, hold, accuracy) is deficient: CONSTRUCT TASKS WHICH DEMAND SPECIFIC SKILL

125

Balance Retraining Overview

- Multifactorial reduction in risk factors
- Early intervention the better
- Programs need to have 5 “V’s”
  - vigorous, vertical, velocity, vestibular, vision
  - Tia Chi, Upright strengthening, group exercise in senior centers, quicker ID of vestibular problems
- Customized Balance retraining
  - Sensory retraining: substitute, compensate, or facilitation using Forced Use Protocols
  - Train Motoric dysfunctions for better righting responses
  - Identify contributing factors to impairment
  - Structure task and environment to get desired movement
- Don’t progress too quickly, develop confidence
- KEEP PATIENT MOVING 40 MINUTES OUT OF 45 MINUTE SESSION

126

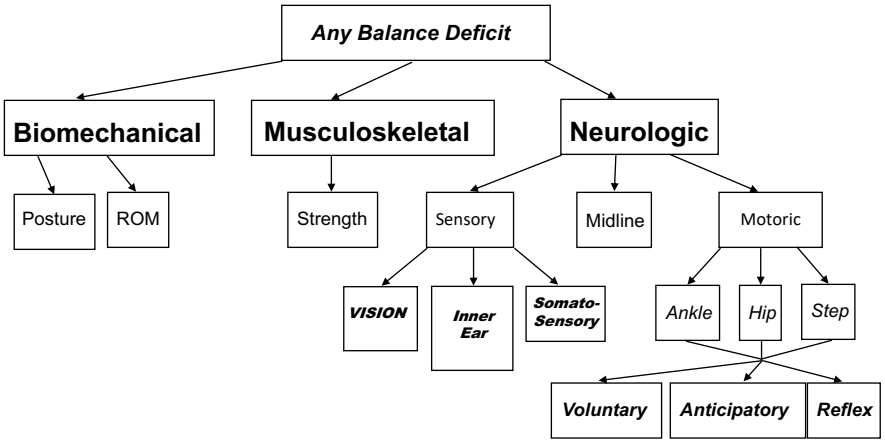
Balance Toys!!

127

What does your gym look like?

128

Balance Intervention (J. M. Holmberg)



129

FACILITATING RELIANCE ON VESTIBULAR CUES: "Inner Ear Push ups"

- Disadvantage BOTH somatosensory & vision
- Foam and eyes closed
- Foam and optokinetic stimulation
- Rockerboard with visual scanning demands
  - Catch throw ball
- Walking on lawn/foam eyes closed
- Counting/dual tasking while walking on foam
- Carrying large object or full glass of water on foam/grass
- VERBAL cues to a sense of VERTICALITY
- May need to start in sitting….

130

Virtual Reality & Immersed OPK……

Stripes to virtual grocery stores, stable ground to moving…

131

132

Cushion Progressions

- Start with cushions 2" and progress to 5" in depth
- Light step-ups onto the cushion w/ & w/o head
- Stepping on/off cushion multiple directions w/& w/o head motions
- Marching in place, w/&w/o head motions
- Weightshift/ leaning exercises eyes open to eyes close increasing ROM
  - Strategy flexibility
- Look behinds, squats, pick up objects and reach

133

Narrowing Feet Balance Drills:

Moving thru somatosensory to increasing vestibular loading

- Eyes Open progression
  - In a safe location, feet comfortably apart, try to hold balance without hands for 20seconds. Gradually move feet closer together in 1 inch progressions until touching.
  - When feet are touching, try advancing one foot forward an inch at a time, holding each position 20 seconds.
  - Final goal is to achieve a full heel-toe position
- Head Motion progression
  - Same as above only try tuning or tilting head 5X each progression
- Eyes Closed progression
  - Same as above only close eyes

134

Direct Vestibular Stimulation

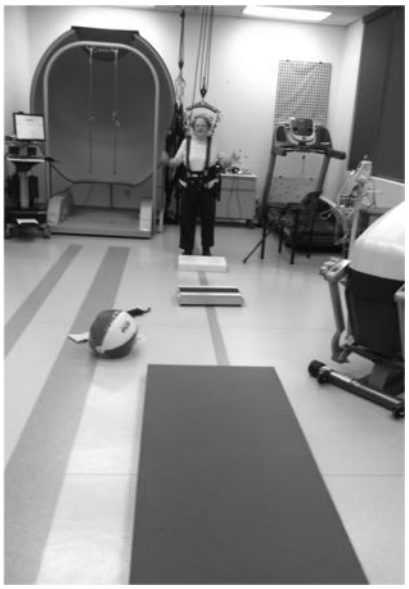
- Change head position and sustain
  - Sustained for otolithic stimulation
- Repetitive head motions for angular stimulation/habituation
- Linear challenges
  - Acceleration/deceleration
  - Treadmill various speeds
  - Trampoline jumping/jogging

135

SENSORY RETRAINING OVERVIEW

- Give patient's progressively harder and harder tasks
- Don't over challenge and promote fear
- To make sensory flexibility more automatic takes:
  - Practice, practice, practice
  - Use cognitive distracters soon into practice
  - Use random practice to promote flexibility
  - Obstacle courses

136



137

Conclusion

- The vestibular system has been found highly plastic and adaptive
- There is a need for skilled differential diagnosis to properly ID vestibular hypofunction
- There are ID optimal facilitatory techniques
- There is power in highly customized vestibular rehabilitation in reducing impairment and disability

138

CONTINUED

Questions?

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139