The Missing Link: Visual and Vestibular Dysfunction Following Concussion (mTBI)

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A Little About Me….

Concussion Signs and Symptoms

• Physical: headache, balance problems, light/noise sensitivity, blurred vision, dizziness, fatigue, nausea, neck pain
• Cognitive: mentally foggy, difficulty concentrating, confusion, delayed processing
• Emotional: irritability, sadness, nervousness, anxiety, lability
• Sleep: drowsy, altered sleep patterns

Duration of Symptoms is highly variable and may last from several minutes to months or even longer in some cases

Risk Factors

• Several risk factors contribute to an athlete’s concussion recovery.
• Assessing the athlete’s concussion history can provide valuable information; specifically, the number of concussions, the severity of each concussion, and how close in time the concussions occurred to each other.
• Additionally, assessing concussion symptoms (number, severity, and duration), the age of the athlete, and any pre-existing conditions (e.g., history of migraines, headaches, ADD/ADHD, Learning Disability, Depression, Anxiety) before the season begins can help with managing a concussion if it ever occurs.

Concussion in 2019
Consensus Statement on Concussion in Sport

• There are 11 R’s associated with SRC management:
  • Recognize
  • Remove
  • Re-evaluate
  • Rest
  • Rehabilitation
  • Refer
  • Recover
  • Return to Sport
  • Reconsider
  • Residual Effects
  • Risk Reduction

Pediatric Considerations

• Based on a previous systematic review of the literature, this guideline includes 19 sets of recommendations on diagnosis, prognosis, and management/treatment of pediatric mTBI. Each recommendation was assigned a level of obligation (ie, must, should, or may) based on confidence in the evidence.

• Supplemental Table via: https://cdn.jamanetwork.com/ama/content_public/journal/peds/937608/psc180001supp1_prod.pdf?Expires=2147483647&Signature=ICLcF5LVKpWOn5CfvIOXhSpwRq0fFCHpM~9aUryRtTZNuPhdYOzgyIXgIzrV-oTPrmsoL0AlN~zQuBELVY7aGvDHNT~b59WfwcFRwAvJHbCg8ygA7ojhxrXp5LXdYxUBGWWH90LKhtxBDK27KR2koN5bEX496Yew7ZIXFcqoq89QUaTJii2XiSCymau8kqLZSGhHblZKqI1oeYM-QzpKN79JW3Ivcu61NwrsBThgYBI1A6H5zXVgugUZ~nNkVyMOKDxsFLdsGSV40VtfXjfdxsONYunz8E8Ki1P0UnoyedU8VrP3x8Tn92gHlwhPLeVPwIGt6dWtfzcu0hOMROQA__.&Key=PairId=APKAIE5G5CRDK6RD3PGA
These visual problems...can be remedied by a range of visual interventions: lenses, prisms, occluders, tints, and VISION THERAPY.

CI and AI were the most common diagnoses...VISION THERAPY had a successful outcome in the vast majority of cases that completed treatment protocol.

The significant change in blood-oxygen level dependent response in the occipital areas following rehabilitative VISION THERAPY...suggests that both depth & vergence may be enhanced.

Cervicovestibular rehabilitation in sport-related concussion: a randomised controlled trial

Kathryn J Schneider1,2, Willem H Meeuwisse1,3, Alberto Nettel-Aguirre2,3,4, Karen Barlow2, Lara Boyd5, Jian Kang1, Carolyn A Emary1,2,3

Results
In the treatment group, 73% (11/15) of the participants were medically cleared within 8 weeks of initiation of treatment, compared with 7% (1/14) in the control group. Using an intention-to-treat analysis, individuals in the treatment group were 3.91 (95% CI 1.34 to 11.34) times more likely to be medically cleared by 8 weeks.

Conclusions A combination of cervical and vestibular physiotherapy decreased time to medical clearance to return to sport in youth and young adults with persistent symptoms of dizziness, neck pain and/or headaches following a sport-related concussion.
Feasibility of Early PT for Dizziness After SRC: a RCT


- Subjects aged 10-23 years old with acute concussion and dizziness were enrolled from sports medicine centers.
- Forty-one participants were randomized into treatment and were seen for physical therapy beginning at 10 days post-concussion.
- Subjects in the experimental group received individually tailored, pragmatically delivered progressive interventions.
- Subjects in the control group received prescriptive sham to minimally progressive interventions.
- The two primary outcomes were medical clearance for return-to-play and symptomatic recovery.
  - The median number of days to medical clearance for the experimental group was 15.5 and for the control group was 26.
  - The median number of days to symptomatic recovery was 13.5 for the experimental group and was 17 for the control.

Multidisciplinary Approach SRC

From withdrawal to return to play:
- Coach
- Athletic Trainer
- Sports Medicine Doctor
- Neuropsychologist
- Neurologist
- Vestibular Therapist (PT/OT)
- Vision Therapist
- Neuro-otologist
- Counselor

“It takes a village to treat a concussion...” Mickey Collins

Multidisciplinary Approach

- Physician (PCM, SM, GP, Pediatrician)
- Neuropsychologist
- Neurologist
- Vestibular Therapist (PT/OT)
- Vision Therapist
- Neuro-otologist
- Audiologist (hearing/vestibular involvement)
- Counselor

Canadian Model of Management

The Visual System Overview
Definition of Vision (Padula)

A **dynamic, interactive** process of **motor** and sensory function mediated by the eyes for the purpose of **simultaneous organization of posture, movement, spatial orientation, manipulation of the environment** and to its highest degree of perception and thought.

**How does vision relate to other sensorimotor systems?**

- **Vision**
  - 4 months post-birth
- **Vestibular**
  - 48 days gestation
- **Proprioception**
  - 3.5 months post-birth
- **VOR**
- **SC & Pulsinlar Pathway**
- **VCR & VSR**

**Sight vs. Vision**

- **Sight** is what allows us to read 20/20
  - Normal Ocular Health
  - Corrective Lenses?
- **Vision** is what the **BRAIN** does with the information taken in from the eyes
  - “Vision is first and foremost action, which makes perception impossible without movement.”

**Vision is the DOMINANT sense!**

**Vision & Motor Link**

**Anatomy of the Eye**
Pathways of Ganglion Cells

- **Parvocellular or P Pathway**
  - **FOCAL**
  - **WHAT?**

- **Magnocellular or M Pathway**
  - **AMBIENT**
  - **WHERE? HOW?**

Parvocellular/Focal/Ventral Pathway

- **Object Identification → WHAT?**
- **Reactive**
- **Slower**
- **Cortical/Higher Level Processing**
- **Guidance of fine motor**
- **Secondary to ambient process in survival**
- **TEMPORAL LOBE**

Magnocellular/Ambient/Dorsal Pathway

- **Spatial Identification → WHERE??**
- **Proactive/Lightning fast/Subconscious**
- **Sensitive to Movement**
- **Spatial Localization**
- **Figure-Ground Segregation**
- **Lager impact on balance/posture/function**
- **Anticipates change in preconscious**
- **PARIETAL LOBE**
Task 1... **Point and maintain eyes** in the direction of the target.

- Hold gaze steady on a target & image steady on the retina
  - **Fixation:** holds the image of a stationary object on the fovea when the head is immobile.
  - **Vestibular (VOR):** holds image steady on the retina during brief head movements.
  - **Optokinetic:** holds image steady on the retina when following object in motion.
  - Fixation is an **active** process, not merely an absence of visible eye movements.

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How do we direct the eyes to a target?

- **Saccades:** bring the image of an object of interest rapidly onto the fovea.
- **Smooth pursuit:** holds the image of a small moving target on the fovea.
- **Vergence:** moves the eyes in opposite direction (i.e., convergence or divergence) so that images of a single object are held simultaneously on both foveae.
Saccades

• Rapid simultaneous shifting of fixation
• 700 degrees/second
• The supplementary eye fields assist in initiating and controlling saccades made during motor movement (of head and body).
• **Voluntary Saccades**: the FEF unlock fixation and begin deliberate movement to visible targets or to the predicted location.
• **Reflexive Saccades**: the parietal eye fields (PEF) begin reflexive/stimulus generated movement based on the abrupt appearance of visual targets.

Saccadic eye movements are a highly coordinated & complex task

Smooth Pursuits

• Stabilizes the image of a small moving target on the fovea
• Cancels the VOR during combined eye-head tracking
• Limited in speed: 30 degrees/second

Task 2...**Coordinate the eyes** to send a single image to the brain.

• Simultaneous movement of eyes in opposite directions to maintain fusion.
  • **Convergence**: adduction of eyes to view an object at near
  • **Divergence**: abduction of eyes to view an object at distance
• Maintaining fusion during vergences involves complex cerebro-brainstem-cerebellar pathways.
Vergence Pathway

- **Stimulus for Vergence Response**: double vision or different positions of image on the retina → fusional vergence movement.
- **Tonic Convergence**: resting state at a particular working distance.
- **Proximal Convergence**: reaction target at near.
- **Accommodative Convergence**: Accomm-Vergence relationship.
- **Fusional**: prompted by double vision.
- **Voluntary**: without a target, at will.

Task 3... **Maintain a clear, steady image on the retina.**

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Dizziness Post Concussion

**Prevalence and Significance**

- Dizziness reported in 55-80% of concussed individuals
- Dizziness associated with protracted recovery
- Undiagnosed vestibular deficits may delay recovery

**Causes of Vestibular Dysfunction in TBI**

<table>
<thead>
<tr>
<th>Type of TBI</th>
<th>Possible Manifestation</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Labyrinthine Concussion</td>
<td>Ataxia, imbalance, BPPV may be present</td>
<td>Most common vestibular injury due to TBI</td>
</tr>
<tr>
<td>Skull Fracture</td>
<td>UBI or UBI (partial or complete) Conductive hearing loss May have both peripheral and central lesions</td>
<td>Common with blows to the scalp, temporal or parietal regions</td>
</tr>
<tr>
<td>Hemorrhage into Labyrinth</td>
<td>May create post traumatic hydrops (Meniere’s type equivalent) Sac lulminal hemorrhage may create acute vestibular damage and bilateral hearing loss</td>
<td>Labyrinthine damage may present with signs and symptoms similar with acute peripheral vestibular damage</td>
</tr>
<tr>
<td>Hemorrhage into Brainstem</td>
<td>Ocular motor signs, poor smooth pursuit, vertigo, perception of tilt Damage to vestibular and ocular motor nuclei</td>
<td></td>
</tr>
<tr>
<td>Increased Intracranial Pressure</td>
<td>Fluctuating hearing loss, vertigo, imbalance</td>
<td>May cause perilymphatic fistula</td>
</tr>
</tbody>
</table>
Just How Important is the Vestibular System?

Vestibular Overview

Vestibular Nuclei

Vestibular Spinal Reflex

• Stabilizes body
• Helps maintain desired orientation to environment

Motor Outputs

• VOR (Vestibular Ocular Reflex): generates eye movements, which enables clear vision while head is in motion
• VSR (Vestibular Spinal Reflex): generates compensatory body movement in order to maintain head and postural stability, thereby preventing falls

Ears and the Brain... Connection

• Head movements are detected by the cupula and transmitted via Vestibular Nerve to the Brain, which then controls eye movement to stabilize the gaze
• The ratio of eye to head movement (GAIN) should be 1:1. Abnormal gain can cause symptoms of blurry vision or vertigo

Vestibulo-Spinal Reflex

• Stabilizes body
• Helps maintain desired orientation to environment

Signs and Symptoms of Dysfunction

• Dizziness
• Blurry Vision
• Nystagmus
• Tinnitus
• Vertigo
• Hearing loss
• Loss of balance & possible falls
• Broad-based stance (to accommodate for imbalance)
• Sweating, nausea, and vomiting (due to ANS involvement)
Cervical Reflexes

The Cervicoocular Reflex (COR)
- Weak reflex
- Does not play direct role in gaze stability
- May help VOR to compensate
- Proprioceptors and somatosensory receptors
  - C1-C2 dorsal nerve roots

The Cervicocollic Reflex (CCR)
- Provides head stability
- Contraction of stretched muscles to align head

The Cervicospinal Reflex (CSR)
- Acts in conjunction with the VSR
  - Provides postural stability through limb activation

6 Degree of Freedom Problem
- Three axes of rotation
  - Roll, pitch and yaw
- Three axes of translation
  - AP, Lateral and Vertical

Navigation Problems
- Motion sensing is a "mission critical" task (need vestibular system to walk reasonably safely in the dark)
- Vestibular System incorporates considerable redundancy

The Peripheral Vestibular System

Inertial Navigation:
- Inner Ear
  - Semicircular Canals are angular rate sensors
  - Otoliths (utricle and saccule) are linear accelerometers
  - Bilateral symmetry means redundant design

Peripheral Vestibular System Functions:
- Stabilization of visual images on the fovea of the retina during head movement to effectively view
- Maintain posture stability especially during movement of the head
- Provide information useful for spatial orientation

Involves the vestibular apparatus in the inner ear:
- Semicircular canals (SCC)
- Utricle
- Saccule
- CN VII: Vestibulocochlear nerve
Orientation of the Semi-Circular Canal
• Anterior
• Posterior
• Horizontal

Labyrinth
- **Bony** section: 3 semicircular canals, the cochlea, and the vestibule. It is filled with perilymphatic fluid (similar to cerebral spinal fluid).
- **Membranous**: is suspended within the bony section and contains membranous portions of the canals and utricle and saccule. It is filled with endolymphatic fluid (similar to intracellular fluid).

Vestibular Hair Cells
• Relative movement of hair cells to head causes change in electrical potential
• During head acceleration, hair cells bend proportionally to head acceleration and change the neuronal (CN VIII) firing rate
• Same general design for hearing

Vestibular Hair Cells and Action Potentials
- **Hirokawa** model: shows the hair cell action potentials in response to different stimuli.
- **Position of Cilia**: normal, negative, and positive.
- **Frequency of Action Potentials**: normal, intermediate, and higher.

The Motion Sensors
- **Ampulla**: contain the cupula (hair cells) which convert displacement into neural firing through bending of hair cells to detect linear/angular motion.
- **Otolith Organ (Utricle and Saccule)**: contain calcium carbonate crystals called otoconia. Shift in these crystals set off neural firing detecting gravity and acceleration.

Ampulla

Cupular Deflection
The otoliths (utricle and saccule) contain a local region of hair cells. Hair cells protrude their processes into a gelatinous matrix called macula which is covered by a surface of otoconia (calcium carbonate crystals).

**Otolith Organ**

The firing rate is increased for ipsilateral linear head movement or tilt and is decreased for contralateral linear head movement and tilt.

**Vestibular Ocular Reflexes**

**Vestibular Reflex**

- **Sensory Organ**: Otoliths (utricle and saccule)
- **Motor Output**: Nerve fibers of vestibular nerve

**Angular VOR**

- Semi-Circular Canals: Horizontal, Anterior, Posterior
- Eyes move opposite to angular movement (rotation) of the head.
- Shaking the head up and down is termed pitch and is sensed by anterior and posterior canals.
- Shaking head side to side or horizontally is termed yaw and is sensed by horizontal canals.

**Linear or Translational VOR**

- Otoliths: Saccule, Utricle
- Eyes move opposite to linear movement of the head.
- Linear movement up and down (riding in elevator) is sensed by the saccule.
- Linear movement horizontally (riding on a train on a straight track) is sensed by the utricle.

**Ocular Tilt Reflex**

- Otoliths: Utricle
- Eyes and head move opposite to the tilt of the head.
- Tilt-UP causes elevation of the left eye, depression of the right eye, torsion of both eyes to the right and the tilt of the head on the body to the right.

**Central Processing**

- 2 Targets for Vestibular Input:
  - Vestibular Nuclear Complex
  - The cerebellum
- Both locations process vestibular sensory input in association with other sensory info (proprioceptive, visual, tactile and auditory).

**Cerebellar Connections**

- The cerebellum is the main adaptive processor.
- Monitors vestibular performance and readjusts central vestibular processing if necessary.
- The cerebellum is the “backup system” for the adaptation of the gain of the VOR.

**Central Processing Proprioceptive Input**

Components of Balance Control

- **Gaze Stabilization System**: maintains gaze direction of the eyes and visual acuity during activities involving active head and body movements. Gaze stabilization and the VOR system are often viewed as synonymous, even though the VOR is only 1 component of gaze stabilization.

- **Postural Stabilization System**: keeps the body in balance while an individual stands and actively moves in daily life.

Visual Dysfunction Following Concussion

- Exotropia or High Exophoria
- Convergence Insufficiency
- Oculomotor Dysfunctions
- Accommodative Dysfunctions
- Spatial Disorientation
- Balance Issues
- Unstable Ambient Vision (Magnocellular)
High Exophoria / Exotropia

Eye Teaming Problem!!!

Exotropia, as shown here, is a condition in which one eye deviates outward.

Misalignment Issues

OCULAR MISALIGNMENT

- Diplopia
- Head tilt (vertical misalignment)
- Noticeable eye turn

If Subtle:
- Difficulty maintaining focus
- Cosmetically normal
- Ocular soreness
- Headaches
- Mental dullness

Vergence Issues

- Convergence: Ability of eyes to turn inward to focus on a near target
- Vergence Testing: Patient fixates on target brought in along the mid-sagittal plane toward the nose
- Near Point of Convergence: when target becomes double
- Normal NPC ≤ 5 cm from tip of nose
  - RECENT RESEARCH

Eye Teaming/Vergence Issues

Vergence Dysfunction Symptoms

- General Symptoms
  - Asthenopia when reading
  - Frontal headaches
  - Intermittent/Constant double vision
  - Squints/closes one eye
  - Letters appear to float/move on the page
- Common Vergence Diagnoses
  - Convergence Insufficiency
  - Convergence Excess/Spasm

Convergence Insufficiency

Double vision makes it difficult to read and comprehend.

The consumption of soft drinks by American youth is increasing. National dietary surveys show that carbonated soft drink consumption more than doubled in youth aged 6 to 17 from about 5 ounces per day in 1977-78 to 12 ounces in 1994-98, the most recent years for which national data is available. Adolescents bely soft drink consumption more than tripled during those years. There are at least two negative aspects to this soft drink explosion. First, the rise of soft drinks is likely related to the rise in childhood obesity. A variety of studies suggest that we don’t eat fewer calories from other sources when we increase calories from beverages. If a child drinks 8 to 10 ounces of a soft drink, that’s equivalent to almost 120 calories.
Oculomotor Issues

Pursuits:
- “Saccadic” pursuits
- “Saccadic Intrusions”
- Symptomatic with pursuits

Saccades:
- Hypometric Saccades
- Slowed Saccades
- Symptomatic with Saccades

Eye Tracking/Oculomotor Issues

- General Symptoms
  - Losing place while reading
  - Skipping words/skipping lines when reading
  - Visual fatigue
  - Difficulty copying from chalkboard or switching fixation distance (i.e. computer monitor to reading material)

- Common Oculomotor Diagnoses
  - Saccadic Dysfunction
  - Pursuit Dysfunction
  - Abnormal Oculomotor Studies

Abnormal Saccades

Abnormal Smooth Pursuits
Accommodative Issues

- Reduction in ability to focus at near
- May prematurely need reading glasses or bifocals
- Accommodative spasm
- Struggle to coordinate accommodation and convergence, leading to difficulty in spatial awareness
- Low blink rate

Eye Focusing/Accommodative Issues

- Failing to clean off your desk before lunch not only raises the risk of spilled food spilling onto your work, but it could also nourish your chances of getting sick. A new report shows that close to half of Americans don’t clean their desks before eating at them, and a third don’t wash their hands, which may force the spread of infectious diseases like colds and flu.

Accommodative Dysfunction

- General Symptoms
  - Blur (distance and/or near)
  - Visual fatigue
  - Headaches (frontal) → neck pain (suboccipital!)
  - Difficulty copying from chalkboard or switching fixation distance (i.e. computer monitor → reading materials)

- Common Oculomotor Diagnoses
  - Accommodative Excess (Spasm)
  - Accommodative Insufficiency

Spatial Orientation & Balance Issues

- Approximately 20% of the nerve fibers from the eyes interact with the vestibular system.
- Patient may misperceive their position in the environment.
- Patient may show a tendency to lean to one side, forward and/or backward.

Unstable Ambient Vision (Magnocellular)

- Decoupling of the focal and ambient processes, which affects function and performance.
  - Deficits in posture, balance, movement, preconscious
  - Loss in speed of ambient visual processing
- M-cells have larger diameter axons and are more susceptible to damage.

Why is the Magnocellular system so susceptible to a brain injury?

- M-Cells have larger diameter axons and are more susceptible to damage.
- If you take out 1 M-cell you lose 6-8 action potentials.
- If you take out 1 P-cell you lose 1 action potential & have plenty of others to pick up the slack.
Unstable Ambient Vision leads to “Focal Binding”

- Causes inability to release detail.
- Environment becomes over-stimulating.
- Movement in the environment (busy, crowded) becomes chaos to the visual system.
- Print on page becomes mass of detail.

Focal Binding & Motor Skills

- Movement becomes conscious and isolates function, lack of automaticity.
- No fluency because system is unable to anticipate.
- May have intact peripheral field, but no peripheral awareness.
- Lack of peripheral awareness makes them more susceptible for re-injury.

Vestibular Dysfunction Following Concussion

- The most common vestibular disturbances after SRC include:
  - Benign paroxysmal positional vertigo
  - Vestibulo-ocular reflex impairment
  - Visual motion sensitivity
  - Balance impairment

Current Evidence (Mucha, 2018)
Neuromuscular Control Deficits and the Risk of Subsequent Injury after a Concussion: A Scoping Review

David R. Howell, Robert C. Lynall, Thomas A. Buckley, and Daniel C. Herman

An emerging area of research has identified that an increased risk of musculoskeletal injury may exist upon returning to sports after a sport-related concussion.

The mechanisms underlying this recently discovered phenomenon, however, remain unknown. One theorized reason for this increased injury risk includes residual neuromuscular control deficits that remain impaired despite clinical recovery.

A total of 32 studies were included in the two reviews (objective 1 n = 10, objective 2 n = 22).

According to a variety of study designs, athletes appear to have an increased risk of sustaining a musculoskeletal injury following a concussion.

Furthermore, dual-task neuromuscular control deficits may continue to exist after patients report resolution of concussion symptoms, or perform normally on other clinical concussion tests.

Therefore, musculoskeletal injury risk appears to increase following a concussion and persistent motor system and attentional deficits also seem to exist after a concussion. While not yet experimentally tested, these motor system and attentional deficits may contribute to the risk of sustaining a musculoskeletal injury upon returning to full athletic participation.
King-Devick Test

• Frontal eye field (Frontal Cortex)
• Dorsolateral prefrontal cortex
• Supplementary motor area
• Posterior parietal cortex
• Middle temporal Area
• Occipital Lobe, Striate cortex
• Thalamus
• Superior Colliculus
• Brainstem structures

Oculomotor Range of Motion

• Looking to see if the eyes move conjugately and smoothly.
• 18-24 inches from patient.
• NOTE:
  • Smooth pursuit eye movements may be slightly saccadic in older people.
  • Small amount of end range nystagmus is normal.
  • Small jump in eye movement as the eyes cross midline is OK.

Pursuits

• Holds images of a moving target on the retina.
• Simultaneously performed with ROM testing.
• Keep target between 2-3 feet from patient.
• 60 degree total arc to avoid end range nystagmus.
• Do not move finger too fast, if you see saccades then try again with slower movements.

Saccades

• Rapid conjugate movements of the eyes to pace the object of interest on the fovea.
• Have patient look between 2 targets approximately 15 degrees apart.
• Nose, pen, nose, pen in left/right and up/down.
• Looking for number of eye movements it takes for patient’s eyes to reach target.
• Normal is ≤ or equal to 2 movements.
• Overshoots are always an abnormal test.
Convergence

• Hold patient’s head stable with finger/target 2 feet away.
• Ask patient to focus on your finger while you move it towards patient’s nose.
• Eyes should converge and pupils should constrict.
• Ask when the patient sees 2 fingers/targets
• Convergence should be sustainable 5 cm from tip of nose.

Maddox Rod = Binocular Posture

Performed @ 33 cm from patient

Binocular Posture Norms

Distance

Near

Stereo Testing

• Stereo glasses worn over regular near point correction.
• To see figures on the right, both maculae must be coordinating together in the brain.
• Left circles give us just noticeable difference (JND) for depth perception.
• >30 sec would be a FAIL.

Binasal Occlusion Screening

• Video on how to do binasal occlusion:
  https://www.youtube.com/watch?time_continue=39&v=JRFlikCWweMc

Vestibular Assessment
Vestibular Ocular Motor Screening Tool (VOMs)

- Brief screening tool used in concussion management
- Track progress and symptom provocation
- Utilization by the non-vestibular practitioner to identify deficits for referral
- Looks at:
  - Smooth pursuits
  - Saccades
  - Near Point of Convergence
  - VOR
  - Visual Motion Sensitivity

Spontaneous Nystagmus

- Holding patient’s head still while they look straight ahead
- Observe for nystagmus

Fixed Gaze Nystagmus

- Hold patient’s head stationary
- Use your finger or pen and take patient to 30 degrees left, right, up and down from center and hold gaze
- Observe for any nystagmus at 30 degrees
- DO NOT TAKE TO END RANGE!!!

What does Nystagmus Look Like?

VOR

- Tilt patient’s head down 30 degrees
- Start slowly moving head side to side while they focus on your nose, gradually increasing speed
- Repeat in vertical plane
- Assessing for integrity of VOR and for both fast and slow speeds

Head Thrust Test

- Grasp patient’s head with your hands and patient focuses on examiners nose, with head tilted down 30 degrees
- Head is rapidly thrust from midline to one side approximate 10 degrees only, repeat other side
- Observe for corrective saccade back to target after thrust
- Repeat at target at a distance as well
- Positive test indicates vestibular hypofunction on ipsilateral side
**Head Shaking Nystagmus**

- Tilt patient’s head down approximately 30 degrees
- Have patient close eyes and you shake their head side to side 20x at 2Hz.
- Have patient open their eyes and fixate on target
- Watch for nystagmus!
- Optimal if performed with VNG goggles or Frenzel lenses!
- If nystagmus present + sign for unilateral vestibular hypofunction

**Visual Acuity/Dynamic Visual Acuity**

- Visual acuity (VA) is acuteness or clearness of vision, which is dependent on the sharpness of the retinal focus within the eye and the sensitivity of the interpretative faculty of the brain.
- Visual Acuity – Static
- Dynamic Visual Acuity – DVA
- *This is your objective measurement of the VOR

**Dynamic Visual Acuity (VOR)**

![Dynamic Visual Acuity (VOR) Image](image)

**Computerized DVAT**

- InVision
- The Dynamic Visual Acuity (DVA) Test
  Quantifies the impact of vestibular ocular reflex (VOR) system impairment on a patient’s ability to perceive objects accurately while moving the head at a given velocity on a given axis.
- Gaze Stabilization Test (GST)
  Quantifies the range of head movement velocities on a given axis over which a patient is able to maintain an acceptable level of visual acuity.

**VOR Cancellation**

- Grasp patient’s head and tilt forward 30 degrees (HC is in horizontal plane)
- Have patient hold thumbs in front of them, arms extended
- You move their head and hands in same direction back and forth observing for ability to keep eyes on moving target while head in motion
- Abnormal test would be saccadic eye movements
Optokinetic Nystagmus

- Normal response
- Eye movement elicited by the tracking of a moving field.
- It differs from smooth pursuit which is the eye movement elicited by tracking of a single distinct target.

What If Optokinetic Abnormal?

Modified CTSIB

- 4 Positions
- 1. Eyes open Solid Surface
- 2. Eyes closed solid surface
- 3. Eyes open compliant surface
- 4. Eyes closed Compliant surface
- Hold each position for 30 secs
- Rate Quality of Balance

High Technology Assessment

What About Dual Task Assessments?

Objective clinical tests of dual-task dynamic postural control in youth athletes with concussion.

- CONCLUSION: To prospectively evaluate sport-related concussion, the performance on balance tests and vision tasks in adolescents and young adults with concussion is evaluable.

Vision Referral/Optical Treatment
When To Refer For an OD Evaluation

- 4 weeks post-injury and still having visual symptoms (or 4 weeks after your treatment begins)
- Postconcussional syndrome
- Depending on patient’s stamina/symptom level could be a 2 hour evaluation.

Optometry & Rehab

- Unfortunately the majority of eye care professionals focus on the central visual system (parvocellular).
- Vision is bi-modal!!!!!!
- Find an optometrist near you that performs neuro-visual rehab
  - Prism
  - Tints
  - Bi-nasal Occlusion
  - Therapy
  - www.covd.org
  - www.noravisionrehab.org

Prescription Glasses

- Depending on age may need more than one pair of glasses.
- Often includes prism...
  - Vertical deviations
    - “First time I felt like myself since the accident.”
  - Base IN prism to improve ambient processing.
  - Gives us a surface to apply binasal occlusion or temporary prism.

Sunglasses/Tints/Overlays

- Patients often have a very immediate reaction to certain tint colors trialed during the exam.
- If positive response then consider tint in Rx.
- Often have patients who initially where sunglasses inside.
  - Particularly students in fluorescent lighting

Case Report

GM, 29 YOAH, involved in MVA on 2/24/18

4/9/18 Visit

- Cover Test: orthophoria at distance
- 5 esophoria at near
- NPC: diplopia 12"/recovery 14"
- Stereo: 70 sec of arc
- Vergence Facility: 0 cpm
- PCSS: 122

A: Convergence Insufficiency
P: Glasses with prism. Continue with vestibular PT. Rtc if symptoms persist or skills plateau

10/24/18 Visit

- Cover Test: orthophoria at distance
- 5 esophoria at near
- NPC: To the Nose
- Stereo: 20 sec of arc
- Vergence Facility: 15 cpm
- PCSS: 78

A: CI - RESOLVED
P: Monitor with annual examinations

Practical Rehabilitation
**Therapeutic Activities/Exercises**

- Principles of Neuroplasticity
- Impairment Specific
- Sensory Overweighting
- Integration of Sport/Daily Activity
- Addition of Exertion

**You Have To Train All Systems!**

- **Convergence Exercises**
  - Pencil Push-Ups (do not overtrain!)
  - Brock String
  - Arrow Chart/Dot Card

**PENCIL PUSH-UPS – WARNING!!!!**

- DO NOT DO IN ACUTE PHASE 
  - FOCAL Binding
- If send home for practice make sure they have someone watching them.
- ODs don't send home pencil push-ups because lacking neuro-cognitive feedback.
- Alternative: use physiological diplopia

**Brock String Progression**

- Need Motor Control
- Ocular Alignment and Physiological Diplopia at each bead
- If not present use "bug on string" exercises to improve
- Progress to speed drills
- Add balance/dual task
- Sport Specific Positions
- VOR + Convergence

**How Do You Make Convergence Functional?**
What about Convergence and Reaction Time?

Convergence and Balance......

Oculomotor Exercises
- 4 Corner Saccades
- Near Far Hart Chart
- Double Hart Chart Infinity Walk
- Complex Charts
- Marsden Ball
- Trails Scanning
- Double Hart Chart Ball Toss

Ambient Processing Exercises
- Central-Peripheral Saccades
- Dynamic Complex Charts
- Wall Ball
- Dynavision
- Peripheral Awareness
- Belgau
- Juggling
- Binasal Occlusion

Accommodation Exercises
- Near Far Hart Chart
- Brock String
- Look Hard/Look Soft
  • with meditation

*LIKELY BENEFIT FROM READING GLASSES...REFERRAL

Functional Accommodative Training....
Adaptation Exercises

• VOR x 1 and x 2 viewing exercises
• Progression:
  - Duration, goal up to 2 minutes continuous
  - Velocity
  - Patterned/Busy backgrounds
  - Position
  - Target Distance

Vestibular Exercises

Vestibular Saliency

Balance and Reaction Time Training
**Substitution**

- Substitution of other strategies to replace the lost or impaired function
  - Eye tracking
  - Oculomotor Exercises
  - Saccades
  - Eye head coordination exercises
  - Remembered Targets

**Progression**

- Adaptation (if there is something to adapt)
- Substitution (this includes oculomotor component)
- Habituation
- Add balance component into all of above or separately

**Loading Activities**

- Balance boards
- Walking Rails
- Bosu Ball
- Head Lamp
- Reaction Time
- Targets in Motion
- Infinity Walk
- Look Aways

- Cognitive Load
- Dynavision
- Trampoline
- Catching/Throwing
- Different Fields of Gaze
- Yoked Prism
- Metronome
- Head Mvmt/Turning

**Cheap Dynavision.....**
CASE STUDIES

Case 1: Collegiate Athlete
Are You Getting to Sport Specific Training?

Case 2: High Achieving Father of 6

Case 3: CEO that Plateaued
“The difference between an average healthcare professional & an excellent one is that the excellent one knows when to get others involved.”

--Eric Singman, MD, PhD--

Questions?

References
