Vestibular and Visual Systems, and Considerations for Hippotherapy

Carol A. Huegel, PT, HPCS

Objectives

- The participant will:
- Have an understanding of the anatomy of the vestibular system and related neuroanatomy
- Have an understanding of the function of the vestibular system
- Understand the interaction of vestibular system on vision
- Be able to perform aspects of vestibular assessment: VOR, static balance
- Recognize signs of vestibular dysfunction: under/over responders
- Realize considerations of vestibular function for evaluation and treatment planning incorporating hippotherapy

Vestibular System
Vestibular System

- Detects movement and gravitational pull
- Provides information regarding head position
- Provides information regarding acceleration/deceleration in movement
- First sensory system to fully develop in utero

Vestibular System

- Affects aspects of physical function, including:
  - Posture
  - Balance
  - Movement
  - Coordination
  - Attention
  - Arousal Level
  - Impulsivity
  - Behavior

3 Components of Vestibular System

- A Peripheral Sensory Apparatus
- A Central Processor
- A Mechanism for Motor Output
REFLEXES

• VOR – Vestibular Ocular Reflex – Generates eye movements to enable clear vision when the head moves.

• VCR – Vestibulocollic Reflex – Acts on the neck musculature to stabilize the head.

• VSR – Vestibulospinal Reflex – Generates compensatory body movement for head and postural stability; helps to prevent falls

The Anatomy

Semi Circular Canals
The Anatomy

Vestibular Nuclear Complex

Embryology
- First sense to develop after conception
- Component parts formed by 8 weeks
- Labyrinth fully formed by 20 weeks
- Vestibular tracts myelinated 2nd trimester
- Lateral semicircular canal last to develop
- System functional 21 weeks
- Central connections immature at birth
Pediatric Considerations

- Vestibulo-spinal system provides postural tone necessary for emergence of early motor milestones, i.e. rolling, sitting, standing
- Vestibulo-ocular system is needed for visual stabilization, acuity, visual spatial and perception abilities.
- Individuals with deficits of the vestibular system since birth or early life will present with motor and/or visual-spatial disabilities.

Postural Control

- Balancing body/center of mass over the base of support
- Involves interplay among sensory, central nervous and musculoskeletal (m-s) systems
- Body position and movement is detected by vestibular, visual and somatosensory systems
- Central nervous system integrates this information for appropriate response
- Response performed by m-s system within appropriate timeframe and with adequate force
Postural Control

- Limits of Stability
- Refers to the boundaries over which one can safely sway.
- Typically, a person standing on a firm surface can sway forward 8” or backward 4” without losing balance or taking a step.
3 Primary Systems for Postural Control

- **Vestibular**
  Provides brain with information about movement and position of the head with respect to gravity and inertial forces.

- **Vision**
  Orients us to the environment.

- **Somatosensory**
  Input from spine and extremities regarding support surface and body position.

SOMATOSENSORY SYSTEM INPUT

- Provides information about the position and motion of the body
- Often referred to as proprioception
- Provides input to vestibular system.
- If vestibular info is affected, balance may be maintained by simply touching a surface with fingertips.

**Vision**

Allows:

- Identification of objects
- Relation of self to objects
- Orientation of self in space/vertical orientation
Vision

- Important component of the vestibular system.
- Approximately 20 percent of visual neurons respond to vestibular stimulation.
- Individuals who have suffered vestibular damage depend on visual cues to maintain their balance. And –
- If that information is removed i.e. in the dark, a person will feel as though they are falling.

The Oculomotor System

- Large Visual field: About 200 feet
- Best vision uses the fovea: Central one degree of the visual field
- Control of the location of the fovea is critical for balance
The Oculomotor System

- 5 Oculomotor control systems keep the fovea on a given visual target:
  - Vestibulo-Ocular Reflex System
  - Smooth Pursuit Eye Movement System
  - Saccadic Eye Movement System
  - Optokinetic Movement System
  - Vergence Movement System

Smooth Pursuit

- The smooth pursuit system moves the eyes in space to keep a single target on the fovea.
- It calculates the speed of the target and moves the eyes accordingly
- It is a voluntary function
- It doesn't operate in the dark
- It is central in nature

Testing Smooth Pursuit
Saccades

- The saccadic system repositions the fovea from one target to another within the visual field.
- It is a conjugate, ballistic movement
- It is extremely fast and accurate
- Saccades don’t require input from the peripheral system and is considered to be central in nature

Testing Saccades

Optokinetic Nystagmus

- The Optokinetic Nystagmus System is used during prolonged head or visual field movements.
- It has both peripheral and central components.
Vergence

- Vergence adjusts eyes for different viewing distances
- Provides depth perception when making associated eye movements
- Influences the VOR during near target head rotation

Testing convergence
The VOR – vestibular ocular reflex – uses peripheral vestibular input. The VOR holds images stable on the retina during brief or rapid head rotations. The semicircular canals provide input as to how fast the head is rotating. The oculomotor system responds by rotating the eyes at an equal velocity and in the opposite direction from the head rotation.
Vestibular Ocular Reflex, VOR

- Function **present at birth**
- VOR poor in neonates
- Absence of VOR at 10 mo is abnormal
- Maturation of VOR and balance with age
Dynamic Visual Acuity

The ability of the cerebellum to recalibrate the neural firing rate coming from the vestibular system is vital to recovery in rehab.

Clinical Dynamic Visual Acuity Test

- Compare visual acuity with the head still vs head moving
- Test visual acuity first with head still
- Then oscillate patient’s head at 2 Hz
- More than 2 lines difference may indicate vestibular deficit

Vestibular Assessment - Adult

- Dizziness Handicap Inventory
- Tinetti Fall Risk
- Dynamic Gait Index (DGI)/Functional Gait Assessment
- Berg Balance Test
- Timed Gait Tests i.e. Timed Up and Go (TUG)
- Standing balance i.e Posturography
- Subjective tests of gait and balance: Activities Specific Balance Confidence (ABC) Scale
- Test for Retropulsion – response when balance is challenged backward
- Romberg
Computerized Dynamic Posturography

- Can be used to quantify aspects of postural control:
  - Ability to maintain quiet stance
  - Ability to shift weight voluntarily
  - Automatic postural reactions

- Not specific for vestibular disorders, but patients with vestibular disorders typically have difficulty maintaining balance when visual/somatosensory cues are altered.

Sensory Organization Test - SOT

- The SOT measures postural sway under conditions with altered visual and somatosensory feedback
- Condition:
  - 1 Stable platform base Eyes open All cues used
  - 2 Stable base Eyes closed No visual cues
  - 3 Stable base Surround moves Altered visual feedback
  - 4 Unstable base Eyes open Altered somatosensory feedback
  - 5 Unstable base Eyes closed Altered somatosensory feedback
  - 6 Unstable base & surround moves Altered visual & somatosensory feedback
Romberg Test

Pediatric Vestibular Assessments

Vsp and VO testing:
- Peabody Developmental Motor Scales Birth – 80 mo
- Bruininks-Oseretsky – 4-14 years
- DeGangi-Berk Test of Sensory Integration 3-5 yr
- Pediatric Balance Scale (modified Berg)

Vsp testing:
- Functional Reach; Timed "Up and Go" test
- Dynamic Posturography Testing

VO testing:
- Dynamic Visual Acuity

Indications of poor vestibular processing
Hypersensitivity to movement
Over Responsive

- Avoids/dislikes playground equipment, ie swings, slide ladders, teeter-totter, merry-go-round
- Prefer sedentary tasks
- Avoid taking risks
- Avoid/dislike elevators and escalators – may prefer sitting rather than standing
- Afraid of heights, even 6” height of step/curb

Over Responsive

- Fearful of stairs, especially going down
- Afraid of feet leaving the ground
- Afraid of being tipped upside down/sideways/back – strongly resist leaning back to wash hair
- As an infant, doesn’t like swings/jumpers
- Fearful of riding a bike
- Appears clumsy

Hyposensitivity to movement
Under-responsive

- In constant motion – can’t seem to sit still
- Craves movement
- Could spin for a long time without appearing to be dizzy
- Seeks out the intense rides at the amusement park
Under Responsive

- Likes to jump on trampoline, cushions on furniture
- Likes being tossed in the air
- Likes to swing as high/long as possible
- Prefers to run, hop rather than walk
- Rocks while sitting

Treatment Interventions

- Hippotherapy
  - Provides movement in all planes
  - Movement can be graded
  - Movement transitions provide acceleration/deceleration
  - Allows for variety of positions
  - Provides visual flow
  - Additional visual targets can be incorporated
Hippotherapy Considerations for Over Responders

In hippotherapy setting:

- Seeks continual physical support
- Fearful of unstable surfaces, i.e., mounting block that is not stable
- Fearful on moving horse, especially tall/large
Under Responders
- Like to jump from heights – including mounting ramp
- Want to “go faster”
- Like to try varying positions, i.e. lying back into supine

Incorporating Equine Movement
Multiple opportunities to grade vestibular input through changes in:
- Velocity
- Tempo,
- Direction
- Incline of equine movement
- Position of the client

Therapists must understand and be able to identify issues and be able to recognize the impact – both positive and negative of equine movement and the equine environment.
References

- Academy of Neurologic Physical Therapy, Vestibular Rehabilitation SIG, Advanced Practice in Vestibular Physical Therapy
- Cronin, Gaye W, Pediatric Vestibular Rehabilitation, Assessment and Treatment
- Natus® Balance and Mobility, Neurocom Balance Systems Balance Education
- Rine, Rosemarie, Introduction to Pediatric Vestibular Rehabilitation, 2016
Thank You