**Objectives**

1. Appreciate the most common diagnoses and causes of vestibular dysfunction in children.
2. Identify vestibular related impairments in children.
3. Consider important factors related to the clinical examination for children with potential vestibular dysfunction.
4. Discuss modifications of interventions based on a child's age and stage of development.

**Diagnoses, Incidence, and Prevalence of Vestibular Dysfunction in Children**

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Combined Sections Meeting, February 4-6, 2015
Indianapolis, IN

**Do children have vestibular related deficits/diagnoses?**

- TBI
- BPVC
- Migrainous vertigo
- Chronic otitis media
- Vestibular neuritis
- Concurrent with SNHL
- Fistula
- Ototoxicity
- Labyrinthitis

- Pendred’s
- 2nd cochlear implant
- Enlarged vestibular aqueduct
- Schwannoma
- BPPV
- Central lesions
- Meniere’s
- Congenital CMV

For those with c/o vertigo – the most common

**Epidemiology Studies**

- Anoh-Tanon et al (2000)
  - 523 (5 yr) pediatric pts seen w/ complaints of vertigo and imbalance referred for otolaryngological tests
  - 27 had normal vestibular tests, but abnormal ophthalmological exams (vergence insufficiency, latent strabismus)
  - 496 had some vestibulopathy (95%)

**Characteristics of VeD in Children**

- Wiener-Vacher (2008) 14 year study
  - Migrainous equivalent (25%)
    - Vertigo w/headache, several hrs (usually fatigue)
    - All tests normal
    - Rx trigger factors, meds only if needed
  - BPV of childhood (20%): 2-3 yoa, no headache
    - 10 minutes or less duration, can function afterwards
    - Testing normal; usually disappears
    - IF IN OLDER CHILD – different cause!!
  - TBI (10%): fx temporal bone or fistula
    - All c/o dizziness within 24 hrs should be tested!
Wiener-Vacher (2008) 14 year study (continued)

- Mondini malformation (malformation of cochlea with bilateral SNHL; enlg aqueduct and enlg vestibule but normal canals)
  - w/mild trauma decompensate- dizzy and imbalance
  - Could be part of other syndrome (e.g. Pendred’s)
- Ophthalmological problems (10%)
- Vestibular neuritis or labyrinthitis (8%)
- Others (23%): SNHI, tumor, OME, BPPV, Meniere’s, vertigo w/epilepsy, psychogenic

Vertigo and Imbalance (Riina et al 2005 - Helsinki)

<table>
<thead>
<tr>
<th>5 year period – school age child visits to otolaryngology (n=119)</th>
</tr>
</thead>
<tbody>
<tr>
<td>19% BPVC</td>
</tr>
<tr>
<td>14% migraine</td>
</tr>
<tr>
<td>12% neuritis</td>
</tr>
<tr>
<td>10% OME</td>
</tr>
<tr>
<td>5% psychogenic</td>
</tr>
</tbody>
</table>

Peripheral and Central Disorders (Salami et al 2006; Italy)

- Children seen in ER w/co dizziness 2-12 yoa
- High incidence of central vertigo (83%)
  - Abnormalities evident with ENG testing
- Causes:
  - Post-traumatic
  - Meningitic
  - Migrainous

Issue with the epi done to date?

- Primarily outside US
- ALL discussed children referred for otolaryngology consult – vertigo
  - How many were NOT referred/tested?
  - Children typically DO NOT c/o dizziness!
- Not really investigating the impairments
  - Gross motor ability?
  - Gaze stability?

TBI

- CDC: incidence 2.3% in children < 5yoa
- Individuals with mTBI have gaze instability and balance problems (Alsalaheen et al 2010; Murray 2014)
- McCaslin, Jacobson & Gruenwald 2011
  - TBI – 500,000 ER visits per year; temporal bone or labyrinth concussion; symptoms can last years

<table>
<thead>
<tr>
<th>Timing</th>
<th>Spont nystagmus</th>
<th>Central ENG findings</th>
<th>Abn calorics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Immediate</td>
<td>46%</td>
<td>43%</td>
<td>21%</td>
</tr>
<tr>
<td>6-12 mos</td>
<td>17%</td>
<td>24%</td>
<td>7%</td>
</tr>
<tr>
<td>2-8 years</td>
<td>18%</td>
<td>12%</td>
<td>6%</td>
</tr>
</tbody>
</table>

Vertigo attacks (Uneri & Turkdogan 2003)

- 34 children 4-17 yoa w/paroxysmal dizziness and/or vertigo
  - 12/34 (35%) chronic headache (not temporally related to vertigo/dizziness)
  - 29/34 (85%) Family hx positive
  - 22/34 (64%) Family hx episodic vertigo
  - 30/34 (88%) c/o motion sickness
- 41% spontaneous nystagmus; 59% BPV
- 4 had mild SNHL (2 ea nystagmus category)
- DX: based on Hx and nystagmus, not decreased caloric responses, is most appropriate
### BPPV in children
- D'Agostino et al. 2003
- Case report of H- BPPV in 10 yo:
  - L side – geotropic nystagmus
  - Vertigo
  - Calorics normal

### Pendred’s Syndrome
- Genetic disorder, resulting in HL
  - Gradual, in stages (often remit and relapse)
- Thyroid typically also affected (goiter)
- 40% have vestibular hypo-function

### Usher Syndrome
- Rare genetic disorder – HL and blindness
  - Retinitis pigmentosa – gradual loss of vision
- Type I
  - born profoundly deaf, lose vision in first decade; balance difficulties & walk late (vestibular loss)
- Type II
  - not born deaf, but hearing loss; no balance problems; lose vision later (2nd decade)
- Type III
  - gradual loss of hearing & vision; they may or may not have balance difficulties.

### Cogan’s Syndrome
- Autoimmune eye inflammation and HL
- Usually occurs after recover from URI
- Eye infection, imbalance and/or dizziness
- With damage to CN – loss of hearing and vestibular hypofunction.

### Congenital Cytomegalovirus
- 0.5-1.0% of infants are infected in the US (Kenneson, 2007)
- Non-genetic cause of SNHL in children
- Preliminary evidence for peripheral VeD and balance dysfunction (Zagolski 2008; Karltorp 2014)
- Histopathologic studies reveal extensive infection in the vestibular organ (Teissier 2011; Gabrielli 2013)
- Vestibular function has not been systematically tested in this population.

### Chronic Otitis Media
- 10% children < 1 yoa
  - Most children had abnormal rotary and VEMP tests
  - Delayed motor development
  - Failed multiple conditions on posturography testing
  - Worse in children with chronic OME, multiple sx
  - Some, not all improved functional abilities after sx
- Mostafa et al (2013)
  - 30-70% have persistent deficits in vestibular function
Ototoxicity

- Medications are known to destroy vestibular receptors
  - High dose antibiotics/aminoglycosides
    - Gentamicin induced in children with CF
  - Chemotheirapies (Knight et al 2005)
    - 61% Rx with platinum chemo, experienced loss of hearing to some degree (vestibular not tested)
    - Rx with cisplatin: 10-85% irreversible ototoxicity

Ototoxicity – Cystic Fibrosis


- Increased survival - intensive Rx of chronic infections with aminoglycoside antibiotics
  - Cumulative dose over lifetime large
- 12 Ss > 5 yrs with CF, no Hx of TBI, no familial Hx HL
  - 2 control grps = children w/CF no ototoxic exposure and those without CF
  - Tested otoacoustic emissions (OAEs) & pure-tone audiometry (PT)
  - Those Rx – significant lower OAEs, but not PT

  Typically affect vestibular receptors even more!!!

Children with hearing loss (HL)

- Huygen et al (Int'l J of Ped Otorhino 1993)
  - 121 children in school for the deaf
  - 41% had VeD confirmed by testing
    - Only canals tested
    - Worse in those with hearing level threshold more than 90dB, and those with acquired loss (e.g. rubella, meningitis).
    - Kernicterus (CNS damage 2 to jaundice)
      - associated with vestibular hyper-reactivity

Children with Sensorineural Hearing Loss (SNHL)

- Rine et al, (Pediatric Physical Therapy 1998)
  - 80% had abnormal PRNT, motor development delay and aberrant responses on dynamic balance test
- Tribukait et al. (Acta Otolaryngology. 2004)
  - Tested canals (calorics) and otoliths (SVV and VEMP)
    - 30% canal areflexia bilaterally, 24% asymmetry
    - 22% weak or absent VEMPS bilaterally + 19% unilateral
    - 32% positive Subjective Visual Vertical
      - 70% had at least 2 abnormal tests, only 30% normal test results

Effect of Cochlear Implantation

- Many with SNHL receive bilateral CI
  - More than 80% reduced or lost otolith fx w CI
  - 60% had reduced gain on VOR test
- Ito (1998) reported 38% of adult patients had vestibular dysfunction following CI.
- Limb et al (2005) reported 982 cases (442 children)
  - 52 (5%) had severe dizziness post op (BPV or unilateral loss of fx)

Effect of Cochlear Implantation (2)

- Jacot et al (2009)
- Followed 224 children receiving implants
  - 50% had normal function prior to sx; 20% complete bilateral areflexia, 22.5% unilateral hypo, 7.5 % bilateral hypo
  - Post CI: vestibular fx changed in 51% of ears with previous normal function (hyper or hypo)!!
Vestibular Fx and Cochlear Implantation

- Fina et al (Otology and Neurology, 2003)
  - Case control study
- 75 children participated
  - Recorded symptoms after implantation
    - 39% experienced dizziness
    - 25% experienced delayed episodic vertigo (74 days post)
- No one has examined motor development or postural control development in these children

** thousands of children receive implants each year typically not referred for testing or rehabilitation

Childhood Paroxysmal Torticollis

- Deonna & Martin (1981)
  - Self limiting, benign
  - Vomiting, pallor, agitation, ataxia (episodes lasting days-weeks) (last 2 through 7 years of age)
  - Typically develop migraine (possible migrainous vertigo)
  - Possible vascular disturbance – basilar migraine

Other Primary Causes of Vestibular Dysfunction in Children

- Late prematurity (12% live births in U.S.; 375,000 per year)
  - Vatovec et al (2001): correlation between VeD and neuro risk
  - Ecevit et al (2012): found significant delays in VEMP response when comparing late preterm to term infants.
- Drug or alcohol exposure in utero (12% U.S. live births)

Incidence of Complaints of Dizziness

- 2012 NHIS Child Balance Supplement
  - 10,954 children 3-17 years of age
  - 5.7% (estimated to impact 3.3 million U.S. children)
  - Only 26% received health care
  - Only 20% had HI

Prevalence: Birth to 5 yoa (24,999,344 in U.S.)

<table>
<thead>
<tr>
<th></th>
<th>VOR</th>
<th>VSR</th>
</tr>
</thead>
<tbody>
<tr>
<td>Late preterm</td>
<td>2%</td>
<td>4.8%</td>
</tr>
<tr>
<td>Chronic OME</td>
<td>18-30% or 4.5 – 7.5 million</td>
<td></td>
</tr>
<tr>
<td>Sensorineural hearing loss</td>
<td>0.11% or 27.5 thousand</td>
<td></td>
</tr>
<tr>
<td>TBI / concussion (50%)</td>
<td>0.02% or 287 thousand</td>
<td>unknown</td>
</tr>
<tr>
<td>Children with school difficulty or autism (mild)</td>
<td>17% or 5.25 million</td>
<td>unknown</td>
</tr>
<tr>
<td>Total</td>
<td>37-49% or 9.25-11.75 million</td>
<td>22-34.17% or 5.5-8.5 million</td>
</tr>
</tbody>
</table>

Impairments in Children with Vestibular Dysfunction

R.M. Rine, P.T., Ph.D.
### What are the effects of loss of vestibular input on:

- balance/development of it?
- motor development?
- functional effectiveness of vision & somatosensation in balance?

### Developmental Implications

- Orientation of head
- Interdependence of systems that work together for function
  - Visual fixation
    - Retinal & non-retinal information
    - Vestibular input
    - Lesion = oscillopsia & impairs reading
  - Postural control
    - Vision, somatosensory, vestibular
    - Lesion – poor balance, motor development

**With lesion of 1, effect noted on functional effectiveness of others!**

### Inter-dependence of Systems

- Systems that work together
  - Must consider
    - Development of each component
    - Effect of 1 on development of each
    - Development of output
      - Balance – vestibular, vision, somatosensation
      - Gaze stabilization – vision, vestibular

### Assessment:

- Function
  - Gross motor
  - Balance
    - Equilibrium response, tilt
    - Gaze stability with head movement
  - Postural control
    - Sensory organization for balance
    - Dynamic testing with EMG
- Vestibular test
  - Screen with HT or mECVCT
  - Diagnostic testing

### What is the Effect of Vestibular Hypofunction (VH) since birth on balance? (Rine et al 1998)
- Seven 4-6 yo children with SNHI since birth
  - six 4-6 yo typically developing children
- Those w/ SNHI
  - Screen motor development
  - Screen vestibular fx
  - Exclusion criteria: hx of orthopedic, cognitive or other neurological impairment
- Compared static and dynamic balance

### What is the Effect of VH on Motor Development? (Rine et al. 2000)
- 28 children with VH since birth (2.5-8.5 yoa)
  - PRNT and rotary chair w/ electronystagmography
  - Gross Motor Scales of PDMS – standard z scores
  - Repeat testing (n=14) 1 year later
- Exclusion criteria: any cognitive, orthopedic or other neurological impairment

**Funded by the APTA Section on Pediatrics**
Progressive Developmental Deficit

• Delayed gross motor (p ≤ 0.03); less w/age
• Longitudinal testing:
  – z scores lower (p < .05)
• Sensitivity of PRNT for identification of progressive deficit = excellent (91%)


What is the Effect of VH on Postural Control?

• 43 children 3-8.5 yoa with SNHI
  – normative sample (n= 34) on posturography testing
• Exclusion:
  – no neurological or orthopedic condition
• Computerized VOR via rotary chair and PRNT testing (room light)

Rine et al. 2000, 2001

Postural Control Deficits

• Increased latency & amplitude of TA (p = 0.04)
• Altered relative latency of soleus and TA (p = 0.05)

Rine et al Control of Posture and Gait. 2001; 40-45

Vestibular & Balance in Children with Chronic OME

• Cohen et al (1997) examined 25 individuals 13-57 months of age (PDMS)
  – Unilateral – no different than peers w/o OME
  – Bilateral: significant delay in locomotor, balance subtests and total score

Vestibular Function and Balance in children with chronic OME
Rine, Corbin, Davis: (2010 APTA AC)

• Vestibular tests
  – Positive HT tests, bilaterally
  – Positive air & bone VEMP bilaterally
• Posturography
  – Above the 75th percentile on conditions 1-3
  – Below the 50th percentile on conditions 4-6 w/ stepping on 5 and 6
• PDMS II
  – Below the 50th percentile & significantly below the norm (p ≤ .05) on the stationary and object manipulation subtests.
• DVA – 1 child refused, all others had positive tests
Post- testing

- Vestibular tests
  - HT & VEMP negative post sx for most
- Posturography
  - All above 50% on 4-6
- PDMS improvement significant (p=0.05)

Children with Chronic OME

  - Children with bilateral OME, significantly impaired
  - Parent perceptions did not correlate
  - Abnormal ENG on 71% of children, related to reports of balance problems
  - 63% of children fell on posturography testing
  - Significant delays on developmental motor testing

Most, not all improved post surgery – Those with hx maintained deficits even with clear ears

Deficits of Balance after mild TBI

(Gagnon et al 2004)

- 38 children (7-16 yoa) each group
  - d/c – considered normal neurologically
- TESTS
  - BOTMP balance subtest
  - P-CTSIB
- Results:
  - Significantly lower on BOTMP (p=0.001)
  - Failed P-CTSIB EC tandem stance

Children underperforming in school

(Franco & Panboca, 2008)

- 88 children 7-12 yoa
- ENT, hearing and vestibular tests
  - Positional tests, nystagmus, rotary & caloric tests (no otolith tests)
  - OKN
- 49% underperforming
- 68% abnormal vestibular tests (compared to 27% of those not underperforming)
  - Unilateral & bilateral irritative lesions in 68%

Importance of Saccular Function

- Shall (2009): 50% cochlear implants; 2/3 had no VEMP responses (saccule fx)
- Walking and balance worse in those with loss at birth or within first year vs later
- Weiner-Vacher – saccule fx maturation correlates with onset of walking in infants

What is the Effect of VH on Gaze Stability?

(Rine & Braswell, 2003)

- DVA Test: Symbols rather than letters
  - Apparatus to control head mov’t
  - Metronome to control speed, 120 deg/s
- Mean of two trials of SVA and DVA
- Good to excellent reliability (ICC(3,1) = 0.82)
Children with vestibular and hearing deficits:

- Like adults:
  - Aberrant postural control & gaze stabilization
- Unlike adults:
  - Sensory organization deficit
  - Vision and somatosensation for balance - deficit
  - Motor development delay that is progressive
  - Do NOT RECOVER or GAIN w/o intervention
- Irritative lesions
  - Reported in children, rare in adults
- Evaluation & Intervention warranted!

Comparison of DVA Scores

<table>
<thead>
<tr>
<th>Group</th>
<th>SVA</th>
<th>DVA</th>
<th>DVA score</th>
</tr>
</thead>
<tbody>
<tr>
<td>Adults</td>
<td>-0.14</td>
<td>0.06</td>
<td>2.0</td>
</tr>
<tr>
<td>3-4.5 yo</td>
<td>0.00</td>
<td>0.16</td>
<td>1.6</td>
</tr>
<tr>
<td>4.6-6 yo</td>
<td>-0.06</td>
<td>0.12</td>
<td>1.8</td>
</tr>
<tr>
<td>6.1-8.5 yo</td>
<td>-0.15</td>
<td>-0.01</td>
<td>1.6</td>
</tr>
<tr>
<td>8.6-15 yo</td>
<td>-0.10</td>
<td>0.05</td>
<td>1.6</td>
</tr>
<tr>
<td>SNHI no VeD</td>
<td>-0.04</td>
<td>0.08</td>
<td>1.3</td>
</tr>
<tr>
<td>w/ BVH</td>
<td>0.01</td>
<td>0.66</td>
<td>6.5</td>
</tr>
</tbody>
</table>


Reading Acuity Test

- Children either read or signed the groups of words as the words got smaller and smaller (by 0.1 logMAR)
- Reading of each group of words was timed
- Children read until words became too small
- Outcomes calculated:
  - critical print size (CPS: the print size that can be read at a normal speed)
  - reading acuity (RA: the smallest print that can be read regardless of speed)
  - critical reading speed (CRS: the speed in words per minute).

What is the Effect of VH on reading acuity? (Braswell & Rine 2006)

- Developed test, based on MnREAD
- Measures:
  - Reading Acuity
  - Critical Print Size
  - Critical Reading Speed

DVA scores – Children w/ VeD and SNHI

- Children with SNHI: (n = 25; mean age = 8.5 yrs)
  - 14 with negative HT test (nVF)
    - 1.5 ± 0.68 lines diff (like normative sample)
  - 9 with positive HT test (BVH) – confirmed by RC
    - 6.6 ± 1.7 lines diff (poor gaze stability)
  - 2 with positive HT test (UVH) - confirmed by RC
    - 3.25 ± 0.35 lines diff (abnormal)
  - DVA score ≥ 3 indicative of failure

What is the Effect of VH on reading acuity? (Braswell & Rine 2006)

- Developed test, based on MnREAD
- Measures:
  - Reading Acuity
  - Critical Print Size
  - Critical Reading Speed

VH and Reading Impairment (Braswell & Rine 2006)

- Children with VH had CPS and RA scores that were significantly lower than peers (hearing or not) without hypofunction
Clinical Tests, Interventions, Cases

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Summary: Incidence

- High incidence of vestibular dysfunction in many pediatric diagnoses
  - Often not tested or reported
- Consider other pediatric diagnoses not systematically tested:
  - Cerebral palsy
  - Myelodysplasia
  - Cytomegalovirus
  - Cystic Fibrosis following drug therapy
  - Childhood Cancer
  - mTBI

Summary: Impairments

- Children with SNHL, Chronic OME, mTBI show evidence for delays in:
  - Balance (Rine 1996)
  - Postural Control (Rine 2000, 2001; Casselbrandt 2008; Gagnon 2004)
  - Gaze Stability (Rine 2003)
  - Reading Acuity (Braswell 2006)

Dizziness Questionnaires

- Dizziness Handicap Inventory
  - Modified by Henriques et al. 2014
    - Studying children with motion sensitivity
    - Ages 7-12
    - Chose 11 total items to ask (max score=44)
    - Added qualifiers to “dizzy” (queasy; vomiting)
    - Positive correlation b/t DHI score and susceptibility to motion sensitivity (p<0.001)
    - Reliability and validity not tested
- Motion Sensitivity Susceptibility Questionnaire (Golding, 2006; modified by Henriques 2014)
- Stay tuned for pediatric DHI (Vanderbilt) and QDEB (National Children’s Study)

Reliability and Diagnostic Accuracy of Clinical Tests of Vestibular Function for Children

Jennifer A. Christy, PT, PhD; Jackson Price, MPH; C.C.A.; Susan Davis, HPA; MHA; Craig Forrest, PhD
Department of Physical Therapy, School of Health Professions (Dr. Christy), and Department of Community Health, Outcomes and Systems, School of Nursing (Dr. Arnes), The University of Alabama at Birmingham, Birmingham, Alabama; Department of Communication Disorders (Dr. Price and Dr. Forrest), College of Arts and Sciences, The University of Alabama, Tuscaloosa, Alabama.

(Pediatr Phys Ther 2014;26:180-190)

Sponsored by the Section on Pediatrics!
**Clinical DVA**
- Chart with LEA symbols
- SVA: Count # optotypes missed on chart
- DVA: Turn head at 2Hz to metronome
  - Count # of optotypes missed on chart
  - Do 2 trials
- DVA Score: Difference in optotypes missed between SVA and DVA

<table>
<thead>
<tr>
<th>CUTOFF SCORE</th>
<th>10</th>
<th>SENSITIVITY</th>
<th>88%</th>
<th>SPECIFICITY</th>
<th>69%</th>
<th>RELIABILITY</th>
<th>ICC</th>
<th>MDC 90</th>
</tr>
</thead>
</table>

**NIH Toolbox DVA**
(Rine et al. 2013, Li et al. 2014)
- Reliability for children 7-17 years (ICC=0.41-0.94)
  - ETDRS symbols were best
- Rate sensor, computer and software ($600)
- Contact:
  - Validity: 50-73% sensitivity and specificity for children with hypofunction
  - www.NIHtoolbox.org
  - J-Slotkin@northwestern.edu
  - Coming soon: NCS DVA (using iPAD)

**Modified Emory Clinical Vestibular Chair Test (mECVCT)**
- Rotating office chair
- Rotate to right (0.5 Hz), 30 sec, EC
- Use IR goggles to time nystagmus
- Rest and repeat to left

<table>
<thead>
<tr>
<th>CUTOFF SCORE</th>
<th>29.2 SEC</th>
<th>SENSITIVITY</th>
<th>63%</th>
<th>SPECIFICITY</th>
<th>100%</th>
<th>RELIABILITY</th>
<th>ICC</th>
<th>≥ 2</th>
</tr>
</thead>
</table>

**Head Thrust**
- 3 trials to each side – random order

<table>
<thead>
<tr>
<th>ICC</th>
<th>75%</th>
<th>77%</th>
<th>≥ 2</th>
</tr>
</thead>
</table>

**Bucket Test**
- 10 trials to each side in random order
- Degrees off center were all < 2 degrees regardless of vestibular function status
- Test-retest reliability (ICC=0.74)
- Implications for children with central Vestibular Dysfunction (e.g. mTBI)

**SOT – vestibular ratio**
- Condition 5/1

| CUTOFF SCORE | 0.20 | SENSITIVITY | 88% | SPECIFICITY | 92% | RELIABILITY | ICC | > 0.75 |
M-CTSIB
- Total score was most reliable
- Mean of 3 X 30 trials per condition
- Total possible score of 120

Cut-off Score
110 sec 88% 85% ICC 0.74 MDC90 16.75 sec

NIH Toolbox Balance Accelerometry Measure (Rine et al. 2013)
- Reliability in children: 8.6-17 yrs (ICC>0.73)
- Correlated with COP and SOT
- Differentiated b/t children with and without vestibulopathy.
- National Children’s Study: Toddler Standing Balance Test for use with ipad.

Pediatric Berg Balance Scale (Franjoine 2003; 2010)
- Note: Ceiling effect in children over 6 years

<table>
<thead>
<tr>
<th>Age range</th>
<th>Cut off (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2 y - 2 y 5 m</td>
<td>23.3</td>
</tr>
<tr>
<td>2 y 6 m – 2 y 11 m</td>
<td>32.7</td>
</tr>
<tr>
<td>3 y – 3 y 5 m</td>
<td>45.4</td>
</tr>
<tr>
<td>3 y 6 m – 3 y 11 m</td>
<td>47.5</td>
</tr>
<tr>
<td>4 y – 4 y 5 m</td>
<td>48.5</td>
</tr>
<tr>
<td>4 y 6 m – 4 y 11 m</td>
<td>50.4</td>
</tr>
<tr>
<td>5 y – 5 y 5 m</td>
<td>53.2</td>
</tr>
<tr>
<td>5 y 6 m – 5 y 11 m</td>
<td>52.2</td>
</tr>
<tr>
<td>6 y – 6 y 5 m</td>
<td>52.8</td>
</tr>
<tr>
<td>6 y 6 m – 6 y 11 m</td>
<td>53.3</td>
</tr>
<tr>
<td>7 y and older</td>
<td>54.6</td>
</tr>
</tbody>
</table>

Functional Reach Test (Donahoe, 1994; Norris, 2008; Volkman, 2009)
- 1 arm reach, similar to adult test
- Measured from 3rd MCP joint; don’t take step; hold 3 seconds
- Did 2 practice and 3 test trials; 5 sec rest b/t trials; took mean of 3 trials

<table>
<thead>
<tr>
<th>Age group</th>
<th>Mean reach (cm)</th>
<th>Standard Deviation (cm)</th>
<th>95% CI (cm)</th>
<th>Suggested Cut-off score (cm)</th>
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</thead>
<tbody>
<tr>
<td>3-4 yrs (n=55)</td>
<td>11.4</td>
<td>2.6</td>
<td>10.7-12.1</td>
<td>6.2*</td>
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<tr>
<td>4-5 years (n=44)</td>
<td>13.6</td>
<td>3.0</td>
<td>12.7-14.5</td>
<td>7.6*</td>
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<tr>
<td>5-6 yrs (n=22)</td>
<td>15.7</td>
<td>4.4</td>
<td>13.8-17.7</td>
<td>6.9*</td>
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<tr>
<td>5-6 yrs (n=22)</td>
<td>21.17</td>
<td>10.5</td>
<td>16.79-24.91</td>
<td>16.79**</td>
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<tr>
<td>7-8 yrs (n=36)</td>
<td>24.21</td>
<td>11.2</td>
<td>20.56-27.96</td>
<td>20.57**</td>
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<tr>
<td>9-10 yrs (n=15)</td>
<td>27.97</td>
<td>4.80</td>
<td>25.56-31.64</td>
<td>25.56**</td>
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<td>11-12 yrs (n=34)</td>
<td>32.79</td>
<td>9.30</td>
<td>29.68-36.18</td>
<td>29.68**</td>
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<td>13-15 yrs (n=10)</td>
<td>32.30</td>
<td>6.10</td>
<td>29.58-36.08</td>
<td>29.58**</td>
</tr>
</tbody>
</table>

*based on 2 SD below the mean
**based on the lower end of the 95% CI – note the large SD, especially in younger groups

Intervention:
Fundamental, Functional, Fun

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Improvement of motor development and postural control following intervention in children with sensorineural hearing loss and vestibular impairment

Rose Marie Rine*, Jennifer Braswell, Donna Fisher, Kelly Joyce, Kristen Kalar, Margaret Shaffer


RCT/Crossover

- N=24
- SNHL since birth
- Control group got attention
- PDMS; SOT; DPT
- Vestibular function tested (21 BVH)
- 3X/week; 30 min; 10 weeks
- Eye-hand coordination; general coordination; eye-head coordination; balance

Visual-Motor Exercises

- Backgrounds on posters or powerpoint
- Head movement in yaw and pitch
- Variables changed at 80% correct responses:
  - Font size (20 point, 16 point, 12 point)
  - Background complexity
  - Speed of head movement
- Walking while viewing background and finding letters
- Reading simple books while standing on compliant surfaces and book is moved
- Sit and spin while identifying letters

Changes in DVA score

SNHI 6 (BVH)
SNHI 10 (BVH)
SNHI 14 (BVH)
SNHI 7 (UVH)
Changes in critical print size by subject

Fun ideas: X1 viewing

- Read a favorite book while turning the head in sitting or standing (yaw and pitch)
- Watch a video or DVD that has small pictures/letters/words that they have to identify while turning the head.
- Jump on mini trampoline while reading flash cards
- Walk or run and chase someone while reading flashcards (flash them quickly)
- Sit and spin: flashcards

Substitution for gaze stability

- Eye-head b/t 2 targets
  - Use 2 siblings to hold pictures/letters/words. The child has to turn the eyes, then the head to identify. Siblings change it each time.
- Imagined targets
  - Child focuses on a picture or word, closes eyes and you change the word or picture as the child turns the head and identifies the new word or picture

Other exercises

- Letters/pictures on tennis ball – play catch, identify pictures
- Catch falling leaves or falling pictures/numbers
- Anything to get head movement and visual focus!
- Re-test DVA after intervention

Dose: Daily; 3X/day; 2-3 exercises

- Before school:
  - Read a book while turning the head (5 pages)
  - Stand on foam with feet together and close eyes for 10 sec/open eyes for 10 sec (5 times)
  - Read 20 flash cards while turning head up and down
- After school:
  - Jump rope while reading flashcards (2 min)
  - Stand on 1 foot (fingertouch) with eyes closed X 2 min
  - Remembered targets X 2 min

- Before bed:
  - Read book while moving it opposite of head turns (2 min)
  - Stand tandem for an entire song while moving arms (5 min)
  - Eye head movement to objects around room while sitting on bed (2 min)
- Follow up weekly to progress. Re-assess after 3 months. It may take longer for kids born with VH.
Habituation

- Determine what motion causes the symptoms
- Find a motion that only provokes moderate symptoms (not too severe, not too mild)
- Do this motion with them 3X/day; 3-5 repetitions.
  - If it makes them sick, you did too much.
  - If they aren’t improving, you might be doing too little.

VR for Concussion: Alsalaheen et al. 2010 (JNPT)

- Retrospective chart review of 114 pts referred for VR following concussion (67 kids, median age 16 yrs):
  - 84 returned for VR (median of 4 visits over 33 days)
- Outcomes:
  - Self report of dizziness, description of dizziness, ABC, DHI
  - DGI, SOT, FTSTS
- Therapy:
  - Gaze stabilization exercises; standing balance; walking with balance challenges (prescribed as daily HEP)

Alsalaheen et al. 2010 (JNPT)

- Most frequent symptom: being off balance (kids and adults) followed by lightheadedness, spinning, nausea and sensation of motion.
- Kids but not adults improved on:
  - Dizziness severity
  - SOT 1 and 2
- Kids were better than adults at:
  - DHI; FGA; FTSTS

Cases

1. 2.5 year old with cytomegalovirus & associated developmental delays
2. 11 year old ambulatory child with cerebral palsy

Testing - Case #1 CMV

- Oculomotor tests (noted during play because of age):
  - Inability to smoothly follow consistently
  - Tends to use saccades to focus eyes
  - Eyes appear to be conjugate with no mal-alignment
- Vestibular tests:
  - Positive head thrusts bilaterally (mirror method)
  - No nystagmus after spinning, no evidence of vertigo or motion sensitivity
- Equilibrium reactions:
  - Delayed tilting response
  - Protective extension present

Testing-CMV

- Somatosensory:
  - No apparent deficits with sensation; unable to test proprioception
- Motor:
  - Limited ankle DF bilaterally and grade of 1+ on Ashworth Scale
    - Child wears bilateral SMO’s in shoes
  - LE strength appears to be good
  - Not formally tested due to age
- Balance:
  - Cannot stand independently but able to stand with very little assistance (finger to the back or 1 hand held assistance)
- PDMS-II reveals that he is functioning well below age appropriate for gross motor
Case #1-CMV

- The child was noted to have balance problems and motor delays due to the following:
  1) Poor oculomotor abilities (central visual problem)
  2) Poor vestibular function (possibly peripheral hypofunction)
  3) Slight spasticity in the ankles (central deficit of the motor system)

Therefore, interventions should focus on the individual deficits as well as the integration component for balance.

Intervention Ideas

- While sitting on a swing that is moving side to side show him various animal stickers and see if he will identify the “dog” “cat” or other animal.
  - Can also do while spinning him in office chair
- While walking in a walker or supported on a treadmill, have him reach out and pick up small objects such as cheerios or stickers (focus during head movement and EHC).
- Work on independent standing while having him watch a video, progress to watching while walking on treadmill

- Work on visual following while supported on a stability ball (move toys side to side/up and down/ present them at various places in the visual field to promote saccades)
- Stand on an incline with knees straight (stretch)
- Work barefoot (strengthening the feet & ankles).
- Work on various surfaces in standing (push somatosensory and vision)

Case #2-CP

- An 11 year old ambulatory child with CP presents with balance problems.
- Her goal is to be able to take dance lessons with her friends.
- She has received PT for most of her life to include several intense therapy sessions (i.e. 3 weeks of “boot camp” like therapy).

Tests-CP

- Oculomotor:
  - Strabismus noted (eyes not aligned when looking straight ahead)
  - Smooth pursuit is intact
  - Saccades: overshoots target 5/10 times
- Vestibular:
  - Must be viewed with caution, due to the abnormal OM exam
  - Negative head thrusts bilaterally
  - Normal DVA test
  - mECVCT: 25 seconds

Tests-CP

- Somatosensory:
  - Inconsistent responses with movement/position sense of toe/ankle
  - Intact light touch
- Motor:
  - Overall LE/UE weakness, right weaker than left
    - Right side, inability to move against gravity
    - Inability to do toe raises, sit ups, or trunk/hip extension
    - Ankle dorsiflexion, poor responses bilaterally
    - Modified Ashworth grade of 2 on the right, 1+ on the left
    - Poor posture noted on plumb line
Tests-CP

- Functional Reach=5 cm
- Falls using protective extension with nudge test
- MCTSIB: falls when standing on foam with eyes closed and uses a hip strategy to stand on foam with eyes open. (score=90/120)
- Unable to do single legged stance
- PBS score=40

Case #2: CP

- This child's balance problems are due to:
  1. Oculomotor deficits (central visual problems)
  2. Somatosensory/motor deficits (central in nature)
  3. Inability to use vestibular information when vision is taken away

Ideas

- Proprioceptive awareness activities (Brain Dance)
- Present objects quickly and unexpectedly to see how quickly she will move her eyes to identify them.
- Work specifically on teaching her to focus her eyes while standing and especially during challenging situations.

Pediatric Vestibular Rehabilitation: A Competency Based Course

THANK YOU!!!
REFERENCES


