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Pediatric Balance Disorders

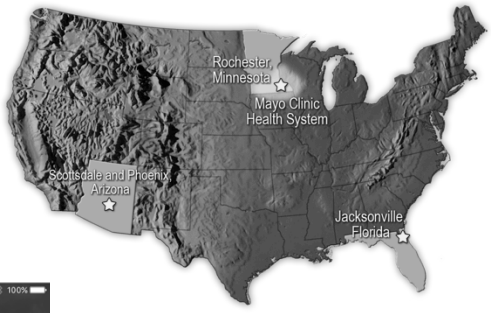
Where We've Been & Where We Are Going presented in partnership with American Auditory Society

Devin L. McCaslin, Ph.D.
Department of Otorhinolaryngology

Audiology
31 May 2017

Mayo Clinic

Locations



Learning Objectives

After this course learners will be able to:

- Describe the functional consequences of a vestibular deficit in children.
- Explain how pediatric self-report outcome measures can be used to identify children with vestibular impairments.
- List evidence-based quantitative assessments that can be used at various ages to identify children with vestibular impairments.

Outline

- Background
- Development of the Vestibular/Balance System
- Balance Deficits in Children
- Research in Identification
- Research in Assessment
- Summary

Case: L.M.

- 12 year old female
- Referred to audiology from ENT
- Chief complaint (3 months)
  - Dizziness
  - Vomiting
  - Frequent Headaches

History

- Social Hx: L.M lives with her father, mother and two sisters. She is in fifth grade and good student. She also in involved in ballet, girl scouts, and soccer.
- Family medical Hx: There is no history of developmental delay or other neurologic or otologic syndromes. Mother does endorse herself as having ocular migraines.

Medication Hx

- **Medications**
  - Motrin 200mg every 6-8 hours as needed for pain
  - Meclizine 25 mg
  - Phenergan 12.5mg as needed for vomiting at

History

- Her initial event of vertigo occurred 3 months prior to the appointment and developed over a period of an hour. She experienced spinning vertigo with nausea and was taken to the ED.
- She is currently trying to continue to practice ballet but because of her symptoms she is unable to do so effectively.
- Reading for school and pleasure seems more difficult to her.

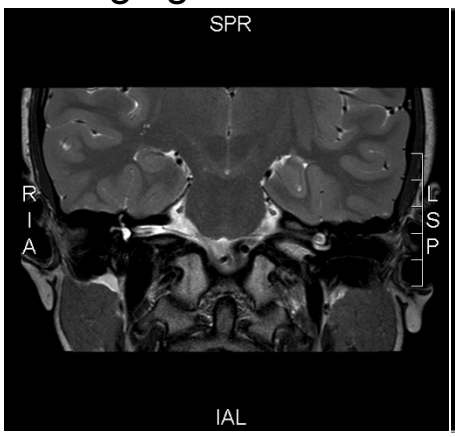
Emergency Department

- March 10, 2010: Emergency Department
  - ED physician
    - Diagnosis: peripheral vertigo, likely etiology: vestibular neuronitis
    - Treatment:
      - Continue meclizine
      - Valium at night
      - Given scopolamine patch
      - Recommended C.H. see a pediatric Otolaryngologist and Neurologist

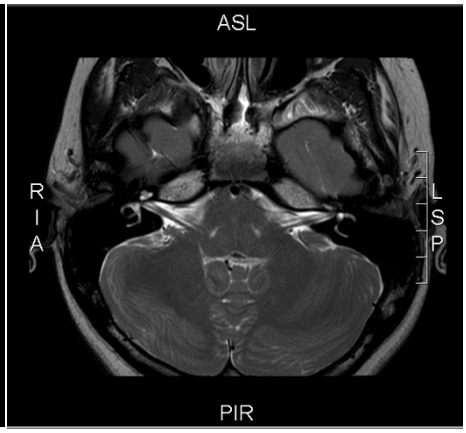
Neurology Consultation

- March 17, 2010: Pediatric Neurology Impression
  - "Vestibulopathy of unclear etiology (not clearly peripheral), debilitating patient. Suspect: migraine-associated vestibulopathy given: constant headache, photophonophobia, nausea/vomiting, carsickness hx.
- Recommendations
  - ENT consult, MRI head

Imaging



Coronal View T2 Weighted

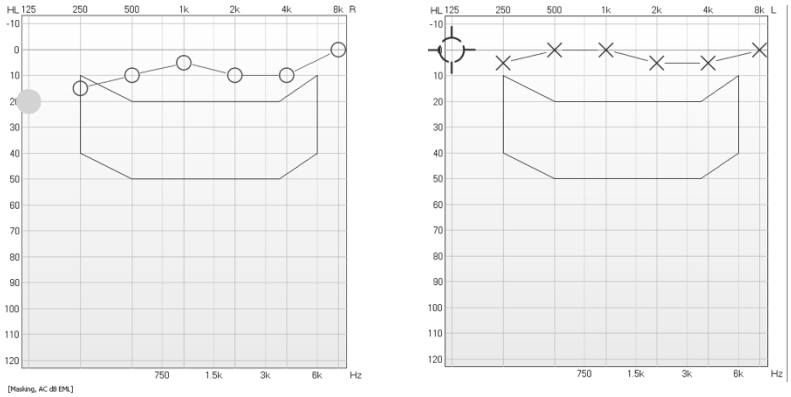


Axial View T2 Weighted

Pediatric ENT Consultation

- April 5th, 2010: Pediatric ENT
  - C/O constant unsteadiness and head movement exacerbates symptoms
  - Difficulty walking, stabilizing self
  - Headaches in mid-frontal region accompanied by nausea
  - Sensitivity to light and sound during headaches
  - Hx of carsickness

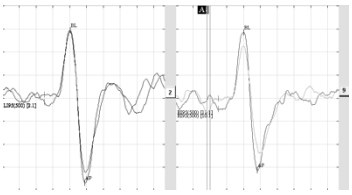
Hearing Evaluation



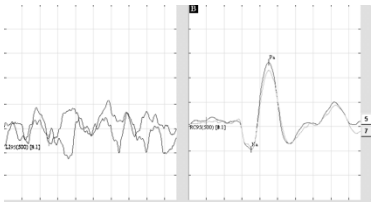
Case: L.HM.

- April 15, 2010: Balance Testing
  - Rotational Chair
  - Ocular Vestibular Evoked Myogenic Potential
  - Cervical Vestibular Evoked Myogenic Potential
  - Videonystagmography
  - Head Impulse Testing

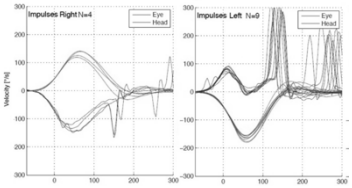
Laboratory Testing



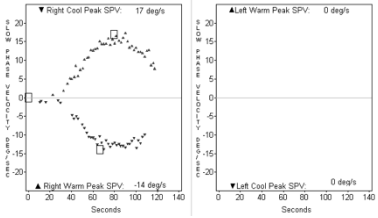
Cervical VEMP



Ocular VEMP



Video Head Impulse



Caloric

Conclusion

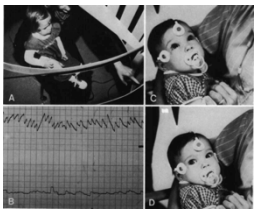
- Vestibular Neuritis: organic impairments are evident not only in adults but children.
- Migraine: is important for correct treatment, therapies, and management
  - Thorough case history and diagnostic inventories
  - Characteristics of pathologies and physical exam findings

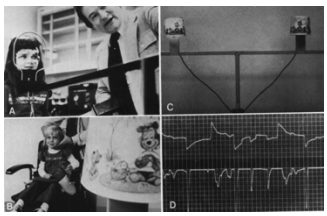
Outline

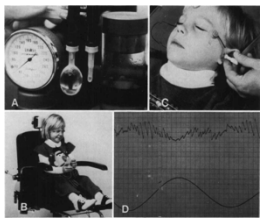
- Background
- The Vestibular/Balance System and Development
- Balance Deficits in Children
- Research in Identification
- Research in Assessment
- Summary

VESTIBULAR TESTING IN CHILDREN

DAVID G. CYR, MA
OMAHA, NEBRASKA







Cyr, D.G. (1991). Vestibular Testing in Children, Ann Otol Rhinol Laryngol Suppl. 1980

Cyr Lab

Cyr, D.G. (1991). Vestibular System Assessment, in Hearing Assessment, 2nd Ed.; Edited. Rintelmann,

Programs Evaluating Children

- Boys Town National Research Center
- Cincinnati Children's
- Dupont Children's
- Vanderbilt University Medical Center
- Sick Kids
- Miami University Medical Center
- University of Tennessee
- Washington University

Outline

- Background
- Epidemiology
- The Vestibular/Balance System and Development
- Balance Deficits in Children
- Research in Identification
- Research in Assessment
- Summary

Epidemiology Studies for Balance

- Until recently, very few studies in children have been conducted in the US. Most studies are undertaken with patients who have had an otolaryngology consult – vertigo
- How do we find children that have vestibular impairments?

- Migraine
- BPVC
- Otitis Media
- Viral Infection
- Trauma

The Predominant Forms of Vertigo in Children and Their Associated Findings on Balance Function Testing

Devin L. McCaslin, PhD*, Gary P. Jacobson, PhD, Jill M. Gruenwald, AuD

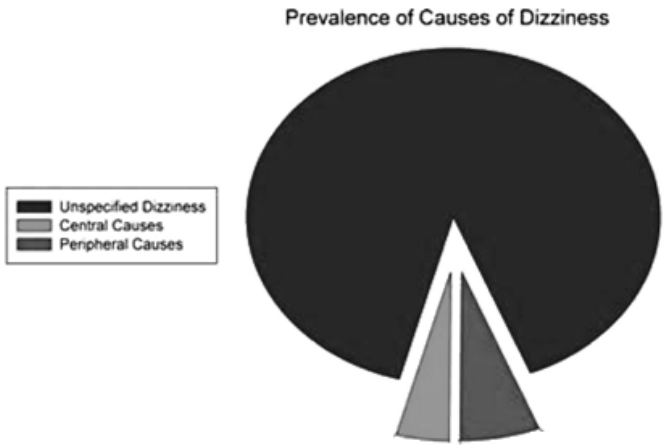
KEYWORDS
• Benign paroxysmal vertigo of childhood
• Migraine-associated vertigo • Electronystagmography
• Trauma • Vestibular neuritis • Otitis media
• Auditory neuropathy • Vestibular

Pediatric Superior Canal Dehiscence

Prevalence

- 1.03% (5,793) of patients 0-18 yoa present with primary complaint related to balance
- 0.45% of patients 0-18 yoa diagnosed with a balance disorder (O'Reilly et al 2010)
  - 4 year retrospective review of a pediatric health system records for ICD9 codes related to balance disorders: 561,151 inpatient and outpatient encounters were reviewed
  - 2,546 pediatric patients diagnosed with a balance disorder

What they found . . .



But…

- Vestibular impairment is the single most common associated feature of SNHL (Cushing, 2015)
- Studies have suggested that up to 85% of children with SNHL have some degree of vestibular impairment (Arnvig, 1955, Cushing et al., 2008, O'Reilly et al., 2011).
- So, 0.45% is likely an underestimation of prevalence in our clinical populations

Epidemiology of Dizziness and Balance Problems in Children in the United States: A Population-Based Study

Chuan-Ming Li, MD, PhD[1], Howard J. Hoffman, MA[1], Bryan K. Ward, MD[2], Helen S. Cohen, EdD, OTR[3], and Rose Marie Rine, PT, PhD[4,5]

- A multistage, nationally representative, probability sample of children (n = 10,954; aged 3-17 years) was examined based on the 2012 National Health Interview Survey Child Balance Supplement.
- Prevalence of dizziness and balance problems was 5.3% (3.3 million US children).
- 36.0% of children with dizziness and balance problems were seen by healthcare professionals during the past year and 29.9% received treatment.

Examining Vestibular Function in Children

- Children will rarely present to the physician with complaints of dizziness or vertigo
  - Limited communication abilities
  - Impairments are compensated for quickly
- This can lead to impairments being overlooked or dismissed.
- It is now possible to determine if functional balance deficit exists, localize the impairment and refer for intervention.

Why does this matter?

- "Kids just compensate"
  - What is needed for compensation (in adults)
    - Strong postural muscles, good vision, stable lesion, and a normal brain
- Effects on gross motor development
- Effects on reading
- Effects on CI failure

Outline

- Background
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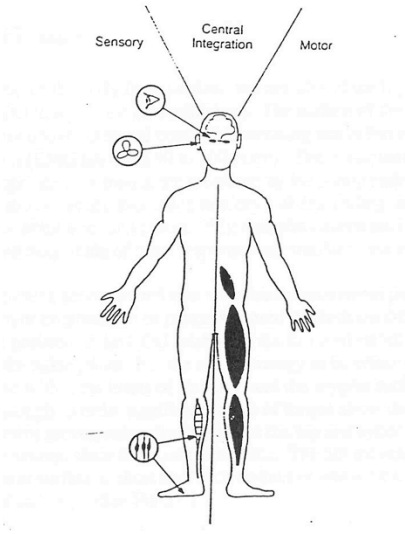
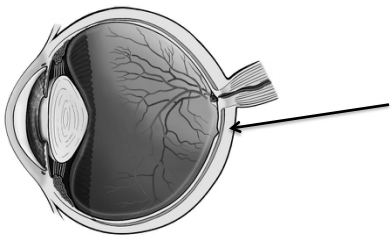
Postural Control

- In order to coordinate the forces required for postural control sensory information must be organized.
- Key components
  - Posturokinetic tasks
  - Environmental context
  - Ontogenesis



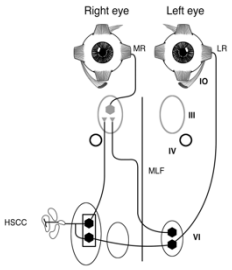
The Ocular Motor System

- Binocular vision is mature by 4-5 months
- Myelination of visual system is mature by 6-7 months
- Retina – mature at 4 years of age

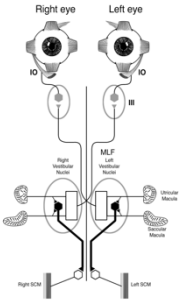


Brecelj J., Doc Opthalmol 2003;107:215–24.

Vestibular Reflexes

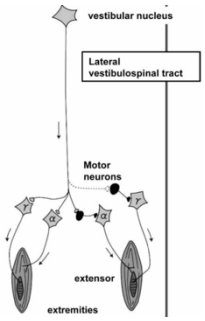


Canal Ocular Reflex



Otolith Ocular Reflex

Otolith Collic Refex



Vestibulo-spinal Reflex

Development of Postural Control

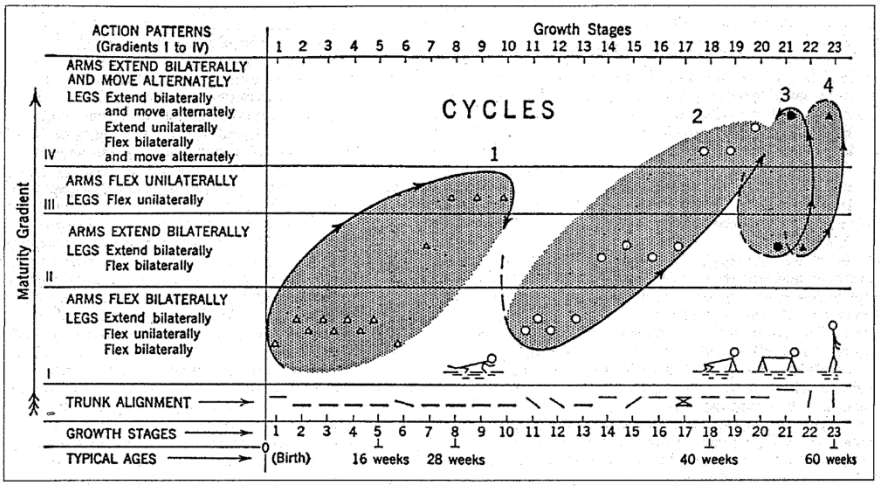


Fig. 13-3. *Growth cycles in the patterning of prone behavior. From Gesell,[5] reprinted with permission.*

Development of Balance

Milestones and Vestibular Hypofunction

Acquisition age of motor milestones in infants and children with hypoactivity of vestibular end organs[a]

	Head control (m)	Crawling (m)	Sitting (m)	Standing with support (m)	Independent walking (m)
Control	3–4	7–10	6–8	10–11	10–12 ($n = 6$)
Group 1a	4–8	7–14	8–15	9–16	17–27 ($n = 8$)
Group 1b	4–16	12–28	14–36	15–348	24–48 ($n = 7$)
Group 2a	3–7	8–24	6–18	9–20	12–33 ($n = 4$)
Group 2b	8–24	15–30	14–36	27–36	44–54 ($n = 4$)

Neurological signs in infants and children with vestibular loss

0–12 months	Hypotonia, floppiness, shuffling
1–2 years	Hypotonia, truncal ataxia, shuffling
2–3 years	Broad base gait, ataxic gait
3–4 years	Broad base gait
4–6 years	Inability to walk on a balance beam
6–10 years	Almost able to stand on one foot with eyes open but unable with eyes closed
After 10 years	Almost able to stand on one foot with eyes closed

Kaga, International Journal of Pediatric Otorhinolaryngology, 49 (1999) 215–224

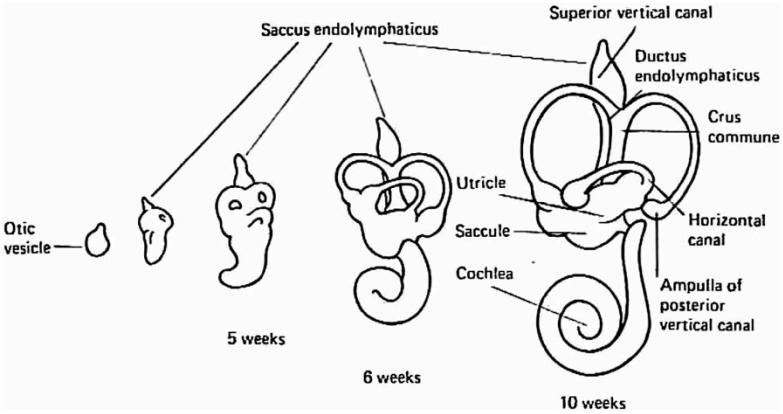
Influence of Sensory Inputs

- Children learning to stand are more influenced by visual cues (7 years of age) than adults.
- Children under 7 years of age are unable to balance efficiently when both somatosensory and visual cues are removed.

Maturation of Balance

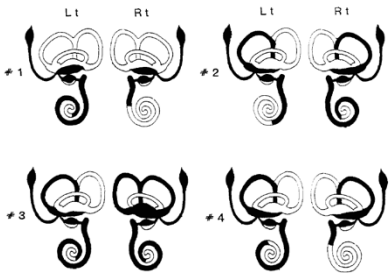
- Important to distinguish between biomechanical and CNS maturation (also any sensory deficits)
- Key Components that Interact
  - Requirements of the task (motivation)
  - Nervous and musculoskeletal systems (rate limiting)
  - Changing environmental conditions (difficulty of the task)

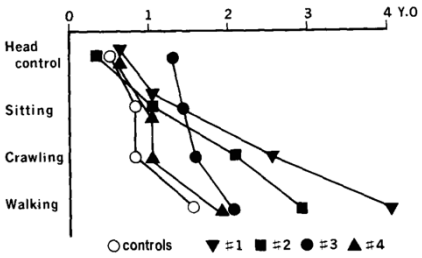
Development of the Ear



Scott-Brown's Otolaryngology, 6th edition

Milestones and Inner Ear Abnormalities





White represents absent portions system.

Tsuzuku & Kaga, International Journal of Pediatric Otolaryngology, 1992

Infant Fine Motor Skills

1. Pull a hanging ring.
2. Pass an object from one hand to the other.
3. Raking small objects.
4. Pull out a peg.
5. Pick up small objects with scissors.
6. Pick up small objects with a forceps.
7. Write a sign with a pencil.
8. Put a small cube into a hole in a box.
9. Take a small object from a bottle.
10. Build a tower with three cubes.

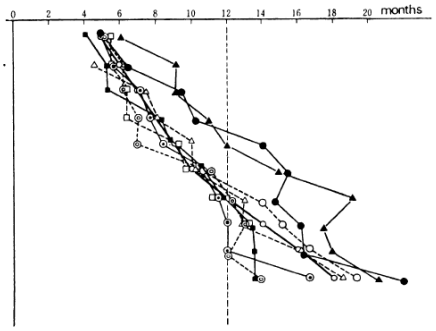


Fig. 9. Comparison of fine motor skills between infants with normal vestibular function and those with impaired vestibular function. ○–○, normal average. White marks indicate normal infants and black marks indicate infants with congenital loss of vestibular function. Fine motor skills are not delayed even in infants with congenital loss of vestibular function.

Kaga, International Journal of Pediatric Otorhinolaryngology, 49 (1999) 215–224

Traditional Milestones (vestibular impairments)

- Typically developing children
  - Infant stepping (2 months-has been reported earlier)
  - Head holding – 2-3 months
  - Sitting/Crawling – 5-6 months (8-18 months)
  - Standing – 10-12 months (9-20 months)
  - Walking with support: 8-9 months
  - Independently ambulating 12 months (12-33 months)

Kaga, International Journal of Pediatric Otorhinolaryngology, *1999*

Outline

- Development of the Vestibular/Balance System
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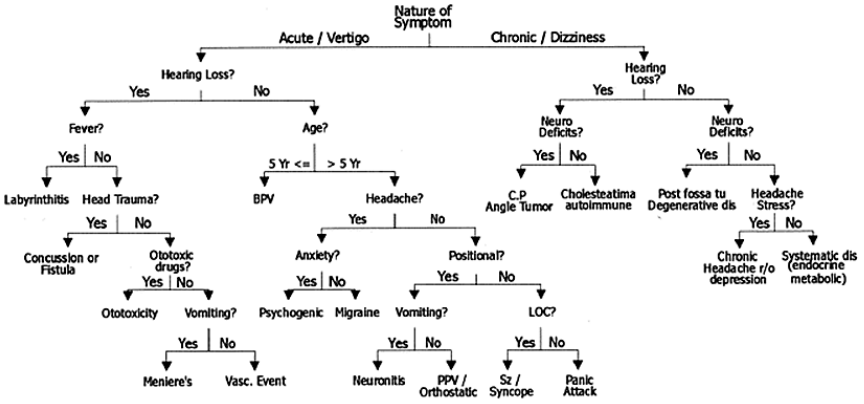
Early Identification-The problem

- Widespread national initiatives for early identification of permanent hearing loss in infants have brought an increased focus to the early auditory development of children.
- It is now well established that hearing loss can delay a child's receptive and expressive speech and language, result in reduced academic achievement, and have significant social consequences.

Early Identification

- The Joint Committee on Infant Hearing (JCIH) endorses early detection of and intervention (EDHI) for infants with hearing loss.
- The goal of EDHI is maximizing speech, language, and literacy development (JCIH position statement 2007).

How do we identify children with balance impairments?



Ravid et al., Pediatr Neurol 2003;29:318

Dizziness Handicap Inventory (DHI)

Jacobson & Newman, 1990

- 25 items evaluating self-reported dizziness handicap
- 3 subscales: functional, emotional, physical
- Each question answered "yes (4 points)," "sometimes (2 points)," or "no (zero points)"
- Minimum score 0 points and maximum is 100 points

Dizziness Handicap for Children?

Contents lists available at ScienceDirect

International Journal of Pediatric Otorhinolaryngology

journal homepage: www.elsevier.com/locate/ijporl

The development of the vanderbilt pediatric dizziness handicap inventory for patient caregivers (DHI-PC)

Devin L. McCaslin [a,*], Gary P. Jacobson [a], Warren Lambert [b], Lauren N English [a], Alison J Kemph [a]

[a] Vanderbilt University School of Medicine, Department of Hearing and Speech Sciences, Division of Vestibular Sciences, Nashville, TN, United States
[b] Vanderbilt Kennedy Center for Evaluation & Program Improvement, Nashville, TN, United States

Purpose

- The purpose of the investigation was to develop a psychometrically sound dizziness disability/ handicap outcome measure for use with a pediatric population between 5 and 12 years of age.
- Items comprising the alpha version of the DHI-P were created based on reports from parents, providers and patients.

Initial Item Generation

- A pool of items comprising the initial version of the DHI-P was generated based on patient reports to caregivers and health care providers.
- The original version of the DHI-P consisted of 40 items selected to maximize both content validity and face validity.

Scoring of the DHI-P

- Each item was a question where the phrase "your child's problem" was used rather than a description of the dizziness.
- Replacing the words "dizzy," "vertigo," and "unsteady" with "problem" makes it possible to use the DHI-P with a broad range of dizziness disorders (e.g. "Does bending over increase your child's problem?").

DHI-P- (40 item)

NAME: DATE:

PEDIATRIC DIZZINESS HANDICAP INVENTORY (DHI)
(Age 5-12)

Instructions: The purpose of this questionnaire is to identify difficulties that your child may be experiencing because of your dizziness or unsteadiness. Please answer "yes", "no", or "sometimes" to each question. **Answer each question as it pertains to your child's dizziness problem only**.

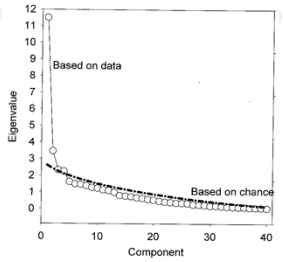
	Yes (4)	Sometimes (2)	No (0)
Does looking up increase your child's problem?			
Does performing more ambitious activities like sports or active play, (running, jumping, etc.) increase your child's problem?			
Do quick movements of your child's head increase his/her problem?			
Does turning over in bed increase your child's problem?			
Because of your child's problem, is it difficult for him/her to walk unassisted?			
Does bending over increase your child's problem?			
Do other people ask if there is something wrong with your child's balance?			
Is your child's balance unpredictable?			
Does your child use a great deal of effort to keep his/her balance?			
Is your child unable to run and move as he/she likes?			
Does your child's problem make him/her feel tired?			

Design

- Phase 1 – Initial item development
- Phase 2- Statistical analysis
- Phase 3 – Test-retest

Phase 1 Results

- A factor analysis showed there to be a single factor (eigenvalue of 11.51) that explained 29% of the total variance.



Phase 1

TABLE 1. α Pilot Study Version of the Pediatric Dizziness Handicap Index with Corrected Item Total Correlation Coefficients

Pediatric Dizziness Handicap Inventory (DHI-P)

Instructions: The purpose of this questionnaire is to identify difficulties that your child may be experiencing because of his or her dizziness or unsteadiness. Please answer "yes", "no" or "sometimes" to each question. **Answer each question as it pertains to your child's dizziness problems only.**

Item	Item Total *r*
Q1. Does looking up increase your child's problem?	0.29
Q2. Does performing more ambitious activities like sports or active play, (running, jumping, etc.) increase your child's problem?	0.37
Q3. Do quick movements of your child's head increase his/her problem?	0.40
Q4. Does turning over in bed increase your child's problem?	0.22
Q5. Because of your child's problem, is it difficult for him/her to walk unassisted?	0.45
Q6. Does bending over increase your child's problem?	0.39
Q7. Do other people ask if there is something wrong with your child's balance?	0.33
Q8. Is your child's balance unpredictable?	0.44
Q9. Does your child use a great deal of effort to keep his/her balance?	0.50
Q10. Is your child unable to run and move as he/she likes?	0.15
Q11. Does your child's problem make him/her feel tired?	0.58
Q12. Is your child's life ruled by his/her problem?	0.58
Q13. Does your child's problem make it difficult for him/her to sleep?	0.37
Q14. Does your child's problem make it difficult for him/her to play?	0.49
Q15. Because of his/her problem, does your child feel frustrated?	0.61
Q16. Because of his/her problem, has your child been embarrassed in front of others?	0.63

Phase 1

- Cronbach's alpha analysis showed that item-total coefficients of this initial data set made it possible to eliminate 15 items reducing the scale to 25 items (i.e. beta version of the DHI-P).

Low item-total correlations

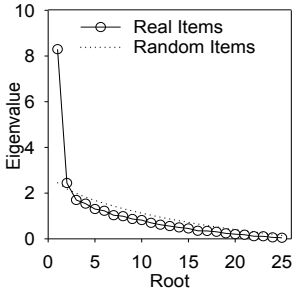
- Deleted examples:
  - Does looking up increase your child's problem?
    - Item total correlation = 0.29
  - Do other people ask if there is something wrong with your child's balance?
    - Item total correlation = 0.33
  - Is your child able to run and move as he/she likes?
    - Item total correlation = 0.15
  - Does your child's problem make it difficult for him/her to sleep?
    - Item total correlation = 0.37

Phase 2

- Based on the results of the analysis of the alpha DHI-p a pool of items was created comprising the beta version of the DHI-P.
- The alpha version of the DHI-P consisted of 25 items selected to ensure that the scale had both content and face validity.

Phase 2

- This analysis once again indicated that there was a single factor (i.e. eigenvalue of 8.30) that explained 8.3 / 25 = 33 % of the total item variance of the 25 item beta version.



Unrepresentative Items

- Because of your child's balance is it difficult for him/her to walk? (phase 1 -.45)
- Is your child's balance unpredictable? (phase 1 -.44)
- Does your child use a great deal of effort to keep his/her balance? (phase 1 -.50)
- Do others find it difficult to understand your child problem? (phase 1 -.45)

Phase 2

- Eliminating these 4 unrepresentative items produced the final version of the DHI-P.
- This scale consists of 21 items and has a maximum score of 84 (i.e. 21 items X 4 points maximum = 84 points).

Test-Retest

- A group of 10 parents (10 females) ranging in age from 26 to 43 years (38 years) (SD = 7 years) were administered the scale at two separate occasions.
- The scale was administered in a face-to-face format on the morning of patients appointment, and then again within 1 month.

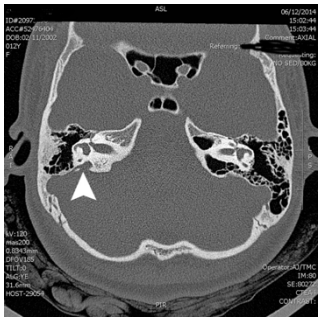
Test-Retest

- Pearson product-moment correlations were computed.
  - The test-retest reliability for the total score was excellent (r = 0.98, P = .000). Paired t - tests on the test-retest scores showed no significant difference (p = 0.742).

What is Significant?

- Interquartile ranges for the total score were calculated for the sample.
  - 0–16 can be classified as no participation and activity limitation.
  - 16–26 is indicative of mild participation and activity limitation while a
  - 26–43 could be classified as moderate.
  - >43 points indicates severe participation and activity limitation (>44 on the adult DHI is severe).

Example of DHI-P
(8 yo with EVA)



PEDIATRIC DIZZINESS HANDICAP INVENTORY (DHI)
(Age 5-12)

Instructions: The purpose of this questionnaire is to identify difficulties that your child may be experiencing because of his or her dizziness or unsteadiness. Please answer "yes", "no", or "sometimes" to each question.
Answer each question as it pertains to your child's dizziness problem only.

	Yes (4)	Sometimes (2)	No (0)
1. Because of your child's problem, is it difficult for him/her to walk unassisted?		X	
2. Does your child use a great deal of effort to keep his/her balance?		X	
3. Does your child's problem make him/her feel tired?			X
4. Is your child's life ruled by his/her problem?			X
5. Does your child's problem make it difficult for him/her to play?		X	
6. Because of his/her problem, does your child feel frustrated?		X	
7. Because of his/her problem, has your child been embarrassed in front of others?			X
8. Because of his/her problem, is it difficult for your child to concentrate?		X	
9. Because of his/her problem, is your child tense?		X	
10. Do other people seem irritated with your child's problem?			X
11. Do you find other people do not understand your child's problem?	X		
12. Is your child's balance unpredictable?	X		
13. Because of his/her problem, does your child worry?		X	
14. Because of his/her problem, does your child feel angry?			X
15. Because of his/her problem, does your child feel "down"?			X
16. Because of his/her problem, does your child feel unhappy?		X	
17. Because of his/her problem, does your child feel different from other children?			X
18. Does your child's problem significantly restrict his/her participation in social or educational activities, such as going to dinner, meeting with friends, field trips, or to parties?		X	
19. Because of your child's problem, is it difficult for him/her to walk around the house in the dark?		X	
20. Because of his/her problem, does your child have difficulty walking up stairs?			X
21. Because of his/her problem, does your child have difficulty walking one or two blocks?			X
22. Because of his/her problem, does your child have difficulty riding a bike or scooter?			X
23. Because of his/her problem, does your child have difficulty reading or doing schoolwork?		X	
24. Does your child's problem make it difficult to successfully do activities that others his/her age can do?		X	
25. Because of his/her problem, does your child have trouble concentrating at school?		X	
Version 2		TOTAL SCORE	

Score 34

EVA and Dizziness

P	Age	Side of EVA	Size of EVA (mm)	DHI-P	Hearing	vHIT	oVEMP	cVEMP	Vibration	Caloric	Rotary Chair	Power Reflectance Peak
1	12	Right	R: 7.1	52	R: ✖ L: ✔	R: ✔ L: ✔	R: ✖ L: ✔	R: ✖ L: ✔	R: ✖ L: ✔	R: ✖ L: ✔ 72% UW	✔	R: ✖ L: ✔
2	8	Bilateral	R: 4.0 L: 3.2	34	R: ✖ L: ✖	R: ✔ L: ✔	R: ✔ L: ✔	R: ✔ L: ✔	R: ✔ L: ✔	R: ✔ L: ✔	✔	R: ✖ L: ✖
3	8	Left	L: 4.0	0	R: ✔ L: ✖	R: ✔ L: ✔	R: ✔ L: ✔	R: ✔ L: ✔	R: ✔ L: ✔	R: ✔ L: ✖ 30%UW	✔	R: ✔ L: ✖
4	6	Bilateral	N/A	0	R: ✖ L: ✖	R: ✖ L: ✖ Anterior canals only	R: ✖ L: ✔	R: ✔ L: ✔	R: ✔ L: ✔	R: ✔ L: ✔	✔	R: ✔ L: ✔
5	9	Left	N/A	6	R: ✔ L: ✖	R: ✔ L: ✔	R: ✖ L: ✖	R: ✔ L: ✔	N/A	R: ✔ L: ✔	✔	R: ✖ L: ✖

Stone and McCaslin, 2014.

Top diagnosis for our Sample

- Migraine
- Head trauma
- Sudden hearing loss
- Waardenburg Syndrome
- Enlarged vestibular aqueduct (EVA)
- Dysplasia
- Cochlear implant users

The Questionnaire for Dizziness, Eye, and Balance (Q-DEB) Function for Children and Adolescents

- Currently, no screening device exists to identify infants, children, and adolescents at risk for vestibular related impairments
- The purpose of this study is to develop a questionnaire to be used for screening vestibular related problems in children fror 1-21 years of age.

Christy, Rine, and McCaslin, APTA 2017

Development of the Q-DEB

- Pilot and feasibility testing of the Q-DEB was completed using hypothetical clinical scenarios as well as participants from UAB, Children's of Alabama, and Vanderbilt University Medical Center.
- Participants were categorized as peripheral vestibular, central vestibular, or typically developing.

Q-DEB

Catches a large playground ball thrown to him/her	Catches and holds with hands away from body	Traps against body	Is unable to do this
Catches a tennis ball thrown to him/her	Catches and hold with hands away from body	Traps against body	Is unable to do this
Throws a tennis ball	Overhand directly to a person or target	Overhand 3-5 feet in random direction	Is not able to throw small ball overhand
Pedaling a tricycle	Able to get on and pedal 5-10 feet	With help to get on it, can pedal 1-5 feet	Is unable to pedal the tricycle
Walking upstairs or a step	Steps up without rail or holding anything	Steps up but uses rail	Is unable to step up onto a step
Walking up multiple stairs	Alternating feet, 1 foot on each step	Steps up placing both feet on each step	Is unable to step up
walking down stairs or a step	Without a rail	Using a rail or someone's hand	Is not able to walk down stairs
walking down multiple stairs	Alternating feet, one on each step	Steps down bringing both feet onto each step	Cannot walk downstairs

Q-DEB
22 Diagnoses Total

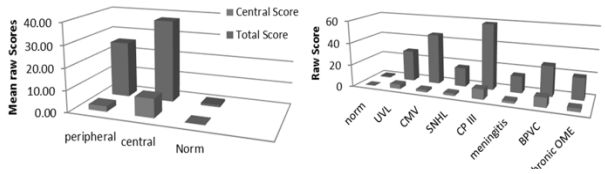
Diagnoses	Infant	Child	Adol
Typically developing	3	9	
Otitis Media with Effusion VH	1		
Concussion		1	6
Migraine		1	4
Enlarged Vestibular Aqueduct		2	
Cytomegalovirus with BVH	1	1	
Sensorineural hearing loss with VH	1	2	

Development of the Q-DEB

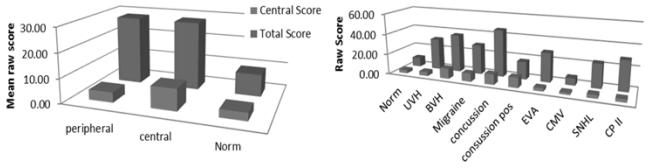
- Item focus for younger children:
  - Acquisition of abilities (i.e. sitting independently with hand free) and identification of abnormalities associated with balance.
- Item focus for older children:
  - Queries the child and parent about dizziness, gaze instability, and a change in the ability to participate in age appropriate activities.

Q-DEB
Results

INFANT (1-5 YOA)

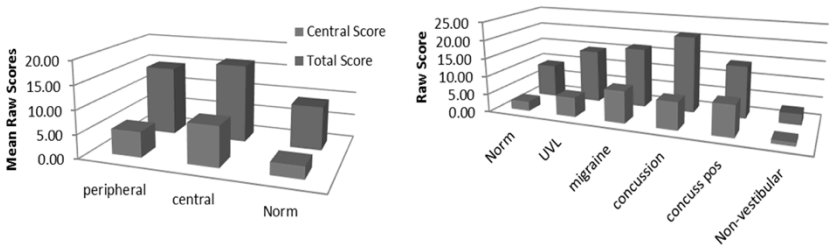


CHILD (6-12 YOA)



Q-DEB
Results

ADOLESCENT (13-21 YOA)



Q-DEB

- Future plans:
  - Reliability testing
  - Comparing Q-DEB results to vestibular function test results
  - Development of use with iPad for ease of administration and scoring

Additional Questionnaires

- The Pediatric Vestibular Symptom Questionnaire: A Validation Study (Pavlou et al., 2016).

Table I. The PVSQ

The following questions ask about how often you feel dizziness and unsteadiness. Please circle the best answer for you.
How often in the past month have you felt the following?

1. A feeling that things are spinning or moving around					
	3	2	3	4	?
	Most of the time	Sometimes	Almost never	Never	Don't know
2. Unsteadiness so bad that you actually fall					
	3	2	3	4	?
	Most of the time	Sometimes	Almost never	Never	Don't know
3. Feeling sick					
	3	2	3	4	?
	Most of the time	Sometimes	Almost never	Never	Don't know
4. A light-headed or swimmy feeling in the head					
	3	2	3	4	?
	Most of the time	Sometimes	Almost never	Never	Don't know
5. Feeling of pressure in the ear(s)					
	3	2	3	4	?
	Most of the time	Sometimes	Almost never	Never	Don't know
6. Blurry vision, difficulty seeing things clearly, and/or spots before the eyes					
	3	2	3	4	?
	Most of the time	Sometimes	Almost never	Never	Don't know
7. Headache or feeling of pressure in the head					
	3	2	3	4	?
	Most of the time	Sometimes	Almost never	Never	Don't know
8. Unable to stand or walk without holding on to something or someone					
	3	2	3	4	?
	Most of the time	Sometimes	Almost never	Never	Don't know
9. Feeling unsteady, about to lose balance					
	3	2	3	4	?
	Most of the time	Sometimes	Almost never	Never	Don't know
10. A fuzzy or cotton wool feeling in the head					
	3	2	3	4	?
	Most of the time	Sometimes	Almost never	Never	Don't know

11. Do any of these symptoms stop you doing what you want to do?
If yes, which ones? .....

Outline

- Background
- The Vestibular/Balance System and Development
- Balance Deficits in Children
- Research in Identification
- Research in Assessment
- Summary

Considerations in Assessment

- Functional balance
- Sensory organization for balance
- Quantitative vestibular assessment

Quantitative Testing

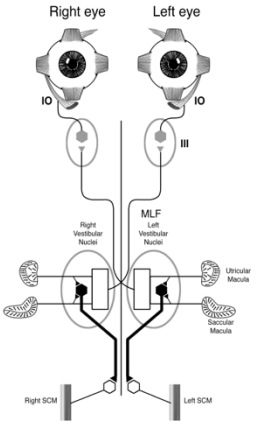
Areas of Assessment to Investigate

- Vestibular Evoked Myogenic Potentials
- Subjective Visual Vertical (utricles-central)
- Rotational Testing
- Ocular Motor Function
- Caloric Response
- Video Head Impulse Testing
- Posturography/Functional balance

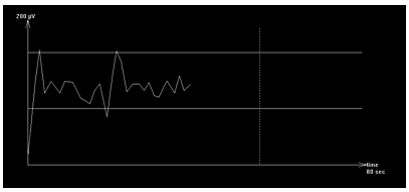
The Effects of Amplitude Normalization and EMG Targets on cVEMP Interaural Amplitude Asymmetry

Devin L. McCaslin, Gary P. Jacobson, Kelsey Hatton, Andrea P. Fowler, and Andrew P. DeLong

- There were 97 subjects, both pediatric and adult
- Assessment of the Saccule
- Looking at comparing cVEMPs across the lifespan



EMG Variability in Children



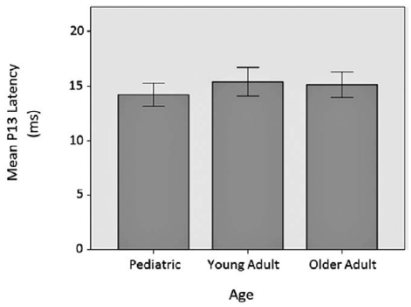
- Adaptations
  - "Friendly" electrodes
  - Visual reference
  - Pediatric visual stimuli
  - EMG-normalization

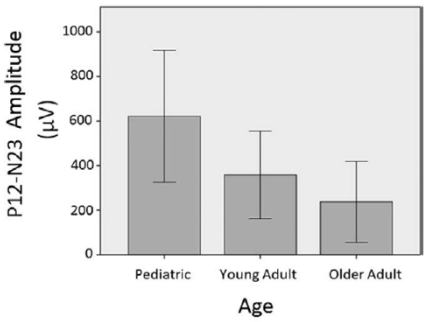
Courtesy of Violette Lavender, Au.D. at Cincinnati Children's Hospital Medical Center

Methods

- The four conditions were:
  - Condition 1- conventional recording,
  - Condition 2 -conventional recording with an EMG target
  - Condition 3 same as condition 1, with the addition of post-acquisition amplitude normalization techniques
  - Condition 4 -same as condition 2, with the addition of post-acquisition amplitude normalization techniques.

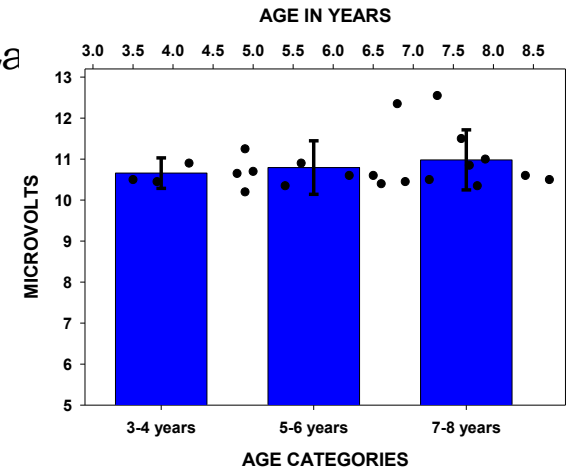
Pediatric cVEMP





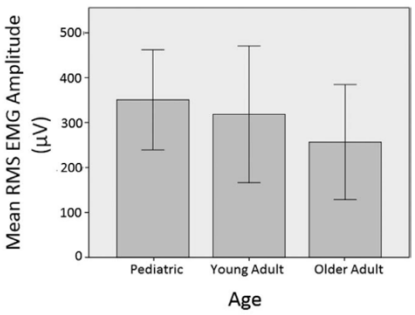
Significant Change in Latency and Amplitude

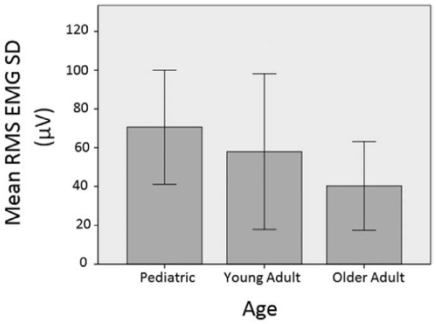
N1 La



Violette Lavendar – Cincinnati Children's

Pediatric cVEMPs





Significant Difference in RMS EMG Amplitude and SD

Effect of Age on cVEMP Asymmetry

GROUP	ASYMMETRY (%)	MEAN + 2sd
Pediatric	12.87	33.75%
Young Adult	16.72	42.84%
Older Adult	20.72	47.86%

Oculomotor Development

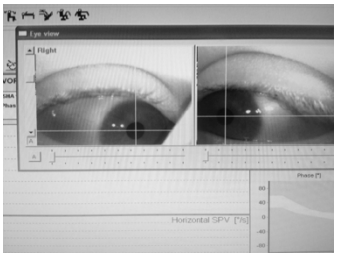
- Development occurs throughout childhood and may not reach adult levels until early childhood.
- Different measurement protocols
  - head fixation and eye position (relative to the target)
  - Target Characteristics
    - size, shape, color, and meaning
  - Analysis techniques
    - extraction and interpolation

Pediatric Oculomotor Findings during Monocular Videonystagmography: A Developmental Study

DOI: 10.3766/jaaa.14089

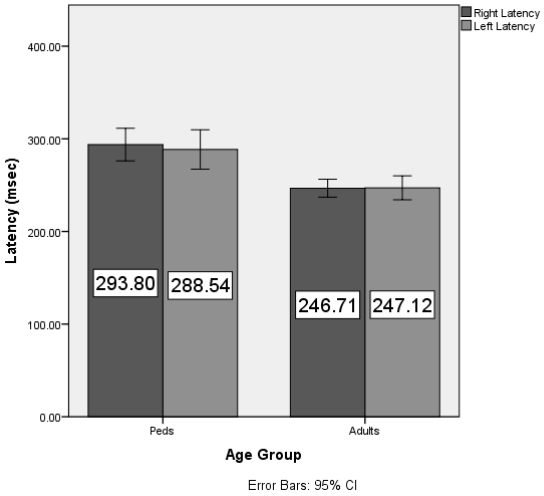
Steven M. Doettl*
Patrick N. Plyler*
Devin L. McCaslin†
Nancy L. Schay*

- To evaluate the effect of age (oculomotor development) on a standard clinical VNG oculomotor test battery.

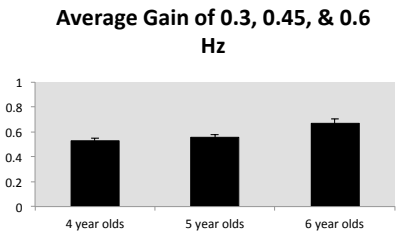


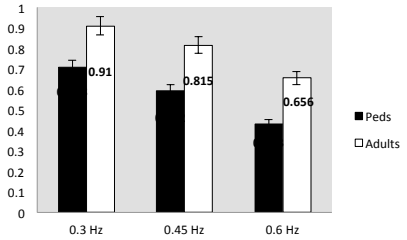
- Does age affect:
  - Saccades?
  - Smooth pursuit ?
  - Optokinetic nystagmus?

Saccade Latency

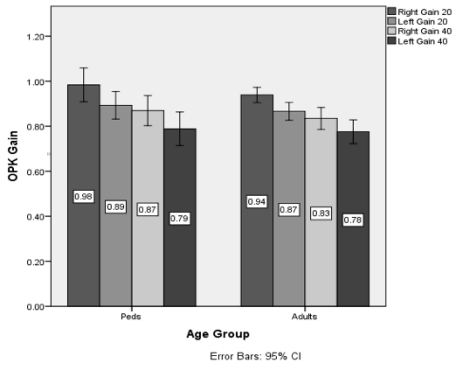


Smooth Pursuit Gain





Optokinetic Gain



Artifact in Pediatric Oculomotor Findings during Videonystagmography: A Retrospective Analysis

DOI: 10.3766/jaaa.16021

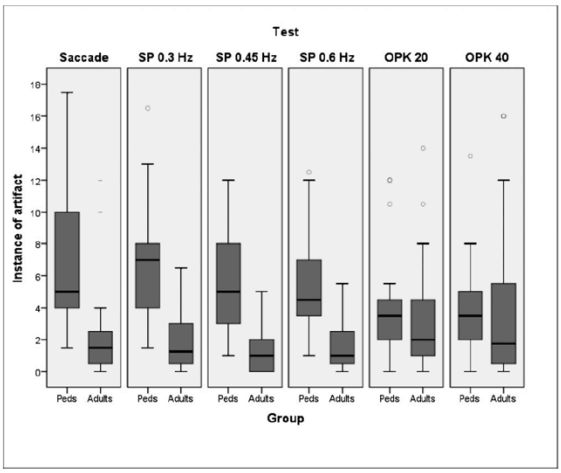
Steven M. Doettl*
Patrick N. Plyler*
Devin L. McCaslin†

Methods

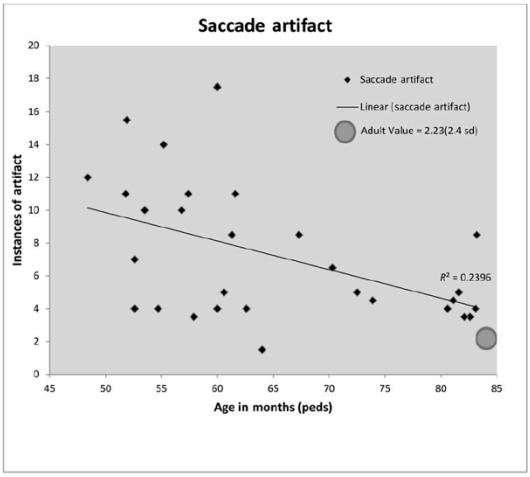
- 63 Subjects
- Group 1 = 30 4-6 year olds
  - 13 – 4 year olds
  - 7 – 5 year olds
  - 9 – 6 year olds
  - Average age of 4.86 years
  - Average vision of 26/20 right eye and 25/20 left eye
- Group 2 = 33 21-60 year olds (Normative range from equipment manufacturer)
  - Average age of 25.2 years
  - Average vision of 20/20 right eye and 18/20 left eye

Artifacts

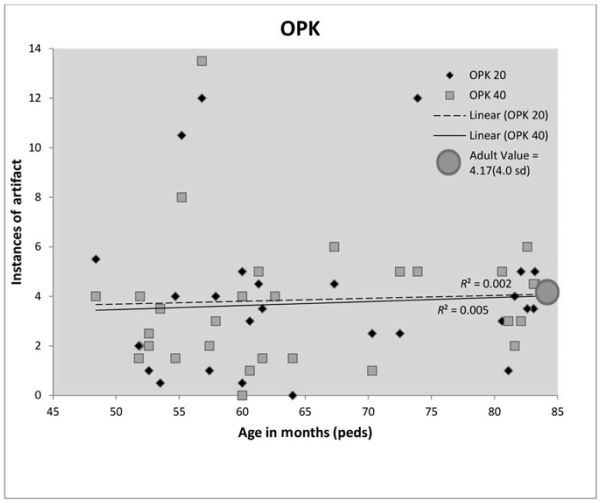
Reflexive



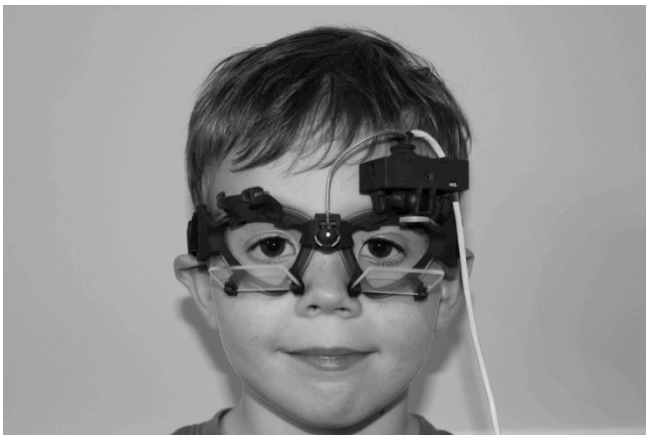
Saccades and Artifact



Optokinetic Testing



Video Head Impulse Testing



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Test-retest and Interrater Reliability of the Video Head Impulse Test in the Pediatric Population

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International Journal of Pediatric Otorhinolaryngology 79 (2015) 1283–1287
Contents lists available at ScienceDirect
International Journal of Pediatric Otorhinolaryngology
journal homepage: www.elsevier.com/locate/ijporl

Video head impulse testing (VHIT) in the pediatric population☆

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International Journal of Pediatric Otorhinolaryngology 79 (2015) 1288–1293
Contents lists available at ScienceDirect
International Journal of Pediatric Otorhinolaryngology
journal homepage: www.elsevier.com/locate/ijporl

Clinical experience with video Head Impulse Test in children

Roland Hülse *, Karl Hörmann, Jerôme José Servais, Manfred Hülse, Angela Wenzel
University Hospital Mannheim, Department of Otorhinolaryngology Head and Neck Surgery, Mannheim , Germany

Subjective Visual Vertical Testing in a Pediatric Population: The "Bucket" test versus the Chronos system

Devin McCaslin, Ph.D.
M Geraldine Zuniga, M.D
Patricia Michelson, B.S.
(Presented at the Association for Research in Otolaryngology)

Purpose

- The purpose of this study was to:
  - develop normative data for two contemporary measures of utricular function in a pediatric population (tilt).
  - determine how measurements of SVV obtained with the Chronos system compared to results obtained from the "bucket test" Zwergal et al. (2009).
  - determine if measure obtained using the Chronos system were replicable when the same participant was retested within a short interval (1 week)

Bucket Test Protocol

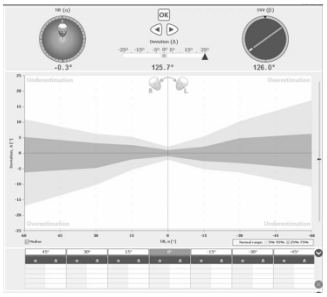
- Subjects looked into a plastic bucket with an luminous line placed in the bottom.
- Starting positions for the bucket were varied randomly.
- The bucket was rotated bucket until the participant indicated (two thumbs up) that the line inside was vertical.

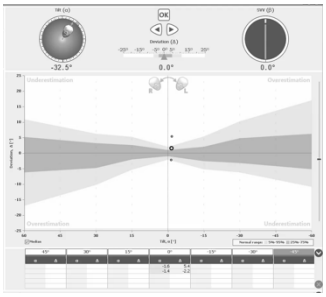
Zwergal et al. 2009.

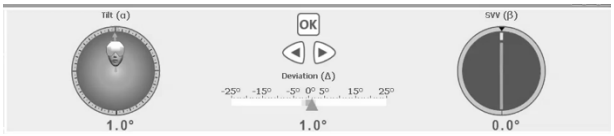
Chronos SVV System Protocol

- cSVV is a computerized system intended to measure a patients SVV.
- The system employs a light-occluding headset with a luminous bar visible to the participant.
- The patient adjusts the luminous line using a Bluetooth wireless controller.

Chronos SVV System

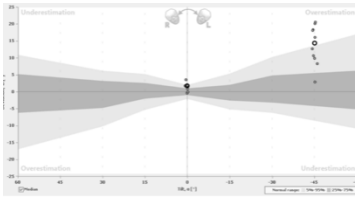






Comparison of Adult and Pediatric Data

	Pediatric Mean	Adult Mean		Adult Std. Deviation	Pediatric Std. Deviation
0 ° Head Center	.449	-.18		2.21	7.05
45° Head Left	-3.27	2.81		8.66	23.94
45° Head Right	4.98	-4.25		9.3	27.13

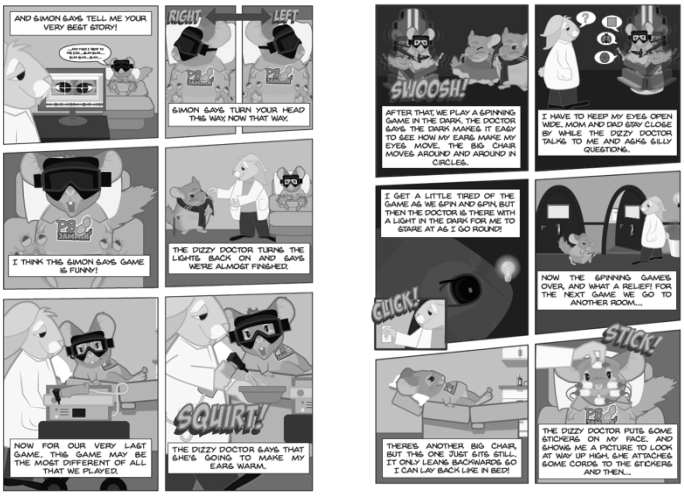


Conclusions

- The variability is higher in children (mean age of 9). Instructions are a key component!
- Test-retest relative reliability for both absolute cSVV and difference angle was fair - good for both cSVV test conditions where the head was tilted.
- Absolute reliability was higher for the bucket at 0 – may indicate the difficulty with the task for children.
- There were significant differences between each condition tested using the cSVV.

Pediatric Materials

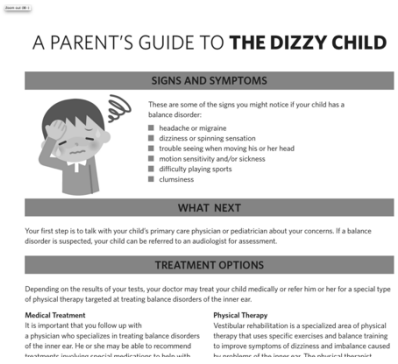
Pediatric Materials



Outline

- Background
- The Vestibular/Balance System and Development
- Balance Deficits in Children
- Research in Identification
- Research in Assessment
- Summary

Awareness



A PARENT'S GUIDE TO **THE DIZZY CHILD**

SIGNS AND SYMPTOMS

These are some of the signs you might notice if your child has a balance disorder:

- headache or migraine
- dizziness or spinning sensation
- trouble seeing when moving his or her head
- motion sensitivity and/or sickness
- difficulty playing sports
- clumsiness

WHAT NEXT

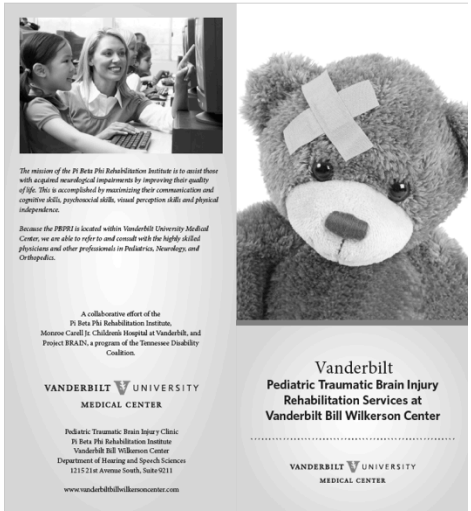
Your first step is to talk with your child's primary care physician or pediatrician about your concerns. If a balance disorder is suspected, your child can be referred to an audiologist for assessment.

TREATMENT OPTIONS

Depending on the results of your tests, your doctor may treat your child medically or refer him or her for a special type of physical therapy targeted at treating balance disorders of the inner ear.

Medical Treatment
It is important that you follow up with a physician who specializes in treating balance disorders of the inner ear. He or she may be able to recommend

Physical Therapy
Vestibular rehabilitation is a specialized area of physical therapy that uses specific exercises and balance training to improve symptoms of dizziness and imbalance caused



The mission of the Pi Beta Phi Rehabilitation Institute is to assist those with acquired neurological impairments by improving their quality of life. This is accomplished by maximizing their communication and cognitive skills, psychosocial skills, visual perception skills and physical independence.

Because the PBPRI is located within Vanderbilt University Medical Center, we are able to refer to and consult with the highly skilled physicians and other professionals in Pediatrics, Neurology, and Orthopedics.

A collaborative effort of the
Pi Beta Phi Rehabilitation Institute,
Monroe Carell Jr. Childrens Hospital at Vanderbilt, and
Project BRAIN, a program of the Tennessee Disability Coalition.

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frontiers in
INTEGRATIVE NEUROSCIENCE

HYPOTHESIS AND THEORY ARTICLE
published: 11 December 2013
doi: 10.3389/fnint.2013.00092

Vestibular activity and cognitive development in children: perspectives

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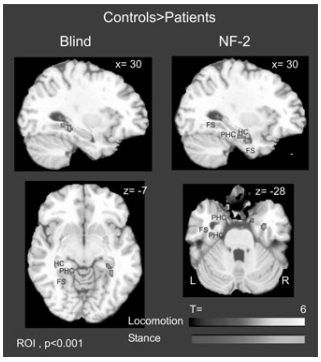
Final thought - Cognitive Development

- Hippocampal system processes information to create episodic and contextual memories.
- Development of orientation and navigation skills have been shown to be decreased in adults with vestibular loss.
- Does a critical period exist?



Jahn et al., Annals of the Ney York Academy of Sciences, 2009

Summary…

- Measures to identify children with balance disorders now exist.
- There are significant differences in the quantitative measures of vestibular function across the lifespan.
- Artifacts during the examination are a constant source of variability in data obtained from children.
- Vestibular impairments will delay milestones the effect of which are not yet entirely known.