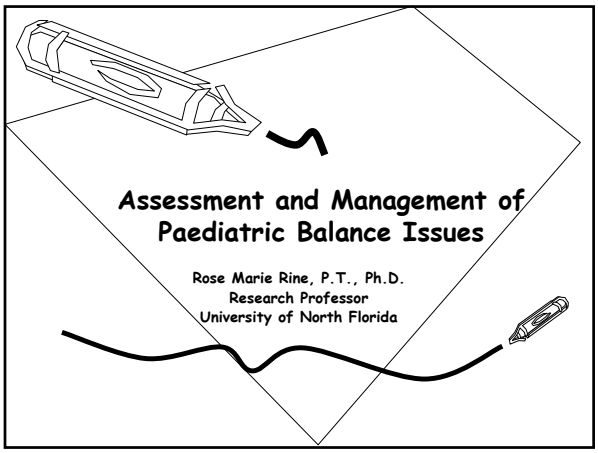

Assessment and Management of Paediatric Balance Issues

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Balance Deficits in Children – what is known?

- CNS lesions
  - Head trauma – motor function deficit;
    - unknown vestibular or postural control
- Cerebral palsy or general motor delay
  - Motor and balance deficits
  - unknown vestibular or postural control mechanisms
- Vestibular deficits
  - Peripheral and central - increasingly identified (OME, BPPV, Meniere's, Migraine, neuritis)
  - Known balance, postural control deficits

Very little research in pediatric balance – needed!!

What we know about balance - adults

- Balance = complex process, multi-sensory & integration + motor
  - Neurological, vestibular or orthopedic problems
  - Static and dynamic balance issues
  - Tests
    - Functional
    - Integrative process - posturography
    - Predictive of falls
    - Validity for vestibular involvement

Fall risk: meds, CNS, weak, incoordination

Balance impairment is NOT always indicative of vestibular deficit

Balance:Issues in Pediatrics

- **Balance**
  - **Known:**
    - **Developmental stages; stage like fashion**
      - **Static & dynamic components – not nec on posturography**
    - **Integrative fx: 4-6 years critical period**
    - **Sensory contributions and functions:**
      - **maturation & change predominant cue for balance**
  - **Loss w/ peripheral vestibular & central lesions**
    - **Rx efficacious – w/ peripheral vestibular deficit**
    - **Dynamic balance related to gait acquisition**

Unknown:

predictive fall tests, relationship to general function or vestibular loss; central lesions not studied

Concern for pediatrics? YES!

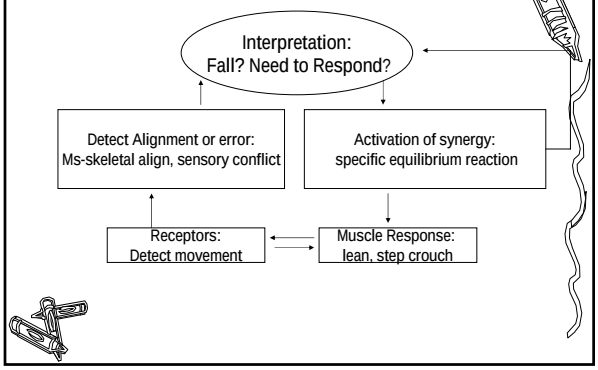
- **Where to begin?**
  - **Developmental changes and measures**
    - **Vestibular, balance/postural control, dynamic visual acuity**
  - **Impairments ?**
    - **Central vs peripheral lesions**
  - **Testing**
    - **Balance, motor abilities, vision abilities, vestibular fx**
  - **Interventions - successful**

Balance vs Postural Control

- ***Balance*** **=**
  - **The ability to maintain COG/COP within the base of support = static**
  - **Control movement of COG to maintain a posture = dynamic**
- ***Postural Control*** **=**
  - **The sensory, motor & integrative mechanisms, substrates & processes required for balance**

To appreciate balance – how develop & deficits – must know the determinants = identity deficits in postural control

Sensory – Motor Integration System of Postural Control



Postural Control

- **Age dependant changes in sensory, motor & integrative components**
- **Comprehensive examination to**
  - **identify & develop remediation for impairments**
  - **Dynamic posturography, developmental, sensory screening enables this type of testing.**

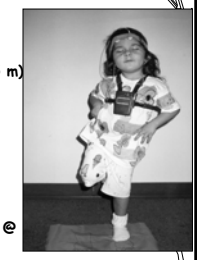
Understanding developmental changes & inter-modal dependency in function is critical for appropriate evaluation and Rx of children.

Balance Function – development

- **Orient in space**
  - **Vision & vestibular – righting – 1-2 mos**
  - **Orientation within any posture**
    - **Step-like emergence –each posture**
    - **Sit – quadruped – standing**
  - **Identification of verticality –**
    - **w/in 2 mos, head erect**
    - **Dep. upon vision & vestibular systems**
    - **SVV 4 yrs of age**
- **Attain, hold and move w/in a posture**
  - **Developmental sequence – evolves**
  - **Dep. upon experience w/in a posture**

Balance: developmental milestones

- Lift head, align eyes w/horizon= 2 mos
- **Sequence:**
  - Static:
    - Assume: sit (6-8 m), stand (10 m)
    - Maintain w/challenge: sit (8m), stand (10-15 m)
  - Dynamic:
    - Move w/in posture: scoot 6-10m, walk (10-18 m)
  - Advanced standing:
    - SLS EO: 3s 3 yr; 6s 4yrs; 10s 54 mos
    - SLS EC: 3s 5 yr; 8s @ 6 yr
    - Turn 180 degrees - 54 mos
    - Balance beam (3.5 in): 4 steps @ 4 yr; 8 ft @ 54 mos.; tandem walk 6 yr
    - Walk on straight line: 5 years



Postural Control Development

- Sensory mechanisms in balance
  - Vision
  - Somatosensory
  - vestibular
- Integration/interpretation
  - Central processes
- Motor output
  - Selection
  - Activation of motor
    - Strength
    - coordination

Postural Control Development

- Sensory mechanisms in balance
  - Somatosensory:
    - adult-like responses in postural control by 3- 4 yoa
  - Vision:
    - binocularity & fusion by 3- 4 yoa
    - adult-like in postural control - adolescent
  - Vestibular (used early, orienting)
    - rotary chair adult-like after 4 yoa, as is VEMP & SVV
    - Not adult like in postural control until after 15 yrs

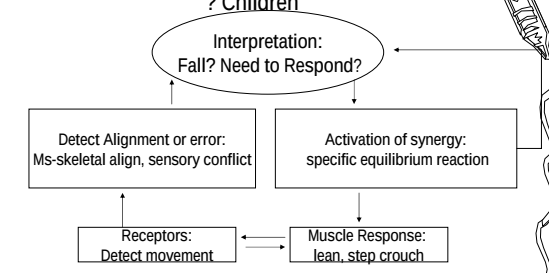
Postural Control Development

- **Sensory mechanisms in balance**
- **Integration/interpretation**
  - **Critical period = 4 - 6.5 yoa**
    - **increased variability**
    - **Difficulty resolving conflicts of sensory cues**
  - **Adult-like after 15 yoa**

Postural Control Development

- **Sensory mechanisms in balance**
- **Integration/interpretation**
- **Motor output**
  - **N-ms response - sequence initially proximal-distal (Woollacott & Shumway-Cook; Nashner)**
  - **Physiologically measured responses**
    - **short latency & long latency responses adult-like between 3 and 4 years (EMG) (Mowatt, Woollacott & Shumway-Cook)**

Sensory – Motor Integration System of Postural Control
? Children



Testing Components for Children- How to identify the problem?

- Functional Balance Abilities
- Mechanisms
  - Postural control integration measures
  - Vision & oculomotor test/screen
  - somatosensory/motor screening
  - Vestibular testing

Functional Balance Testing

- Standardized <u>norm referenced</u> testing (PDMS II & BOTMP II)*
  - balance sub-tests
  - eye-hand coordination
  - milestones
- Functional Reach
- Berg Balance Scale

*Peabody Developmental Motor Scales
Bruininks-Oseretsky Tests of Motor Proficiency

PDMS - sample

Functional Reach

- **Functional Reach: norms for 5yo and up**
  - **5-6 6.7 in; 7-8 yrs 8.2 in**
  - **9-10 yrs 10.2; 11-12 yrs 11.9 in**
  - **13-15 yrs 11.8 in (adult 20-39 yrs 16.7)**

  (Donahue, Turner and Worrell)

**** None adjusted for height!**

Functional Reach – Control ht & arm position

- **Adults & children**
- **Measure:**
  - **Center of pressure (COP), kinematics and reach @ shoulder & pelvis**
  - **UE crossed and not**
- **Results: adjusted for height/arm position:**
  - **over 7yoa & adults similar**
  - **To correlate w/COP, UE crossed, measure from pelvis (adult) or shoulder (child)**

- ***Correlate with gait - children with CP***
- ***(Rine & Moore, 2005; Moore & Rine 2007, 2009 ISPGR)***

Pediatric Berg Balance Testing

- **Test balance @ functional not impairment level; not diagnostic**
- **8-12 yo children w and w/o CP (mean age 10)**
  - **Berg Balance Scale**
  - **Gross Motor Functional Measure (GMFM)**
- **Those with higher GMFM scored higher on Berg**
- **15 min to administer**

	BBS score (56 max)	GMFM (111 max)
Sp hemi	53.2	100.3
Sp diplegia (aids)	49.7	88.4
Sp diplegia (no aides)	25.1	37.6
No motor impairment	55.9	110.9

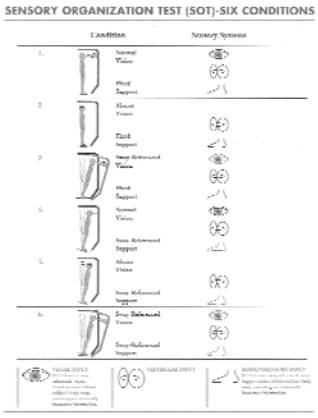
Kembhavi et al Pediatric *Physical Therapy; 2002*
Franjoine MJ, Gunther JS, Taylor MJ, *Pediatric Physical Therapy 2003*

Testing Components for Children

- Functional Abilities
- Postural control measures –
  - Integration & sensory-motor output
- Vision & oculomotor testing, screening
- Vestibular testing

Posturography: SOT & Dynamic testing

Interpretation dependent upon sensory and motor test results



Testing Components for Children

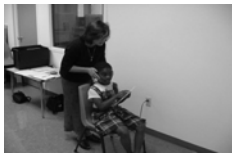
- Functional Abilities
- Postural control measures
- Vision & oculomotor testing, somatosensory/motor screening
- Vestibular testing

OM Screen – tracking and ROM
adult like by 2-3 yrs.

Vision Screen -OKN

- Patient to watch vertical stripes pass by
- Observe nystagmus
- Normal = for 1-2 beats

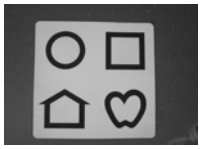
Vision & Gaze Stabilization Testing



- Static & dynamic visual acuity
- HT (vestibular screen) adult-like

Dynamic Visual Acuity

- Dynamic Visual Acuity
  - Acuity w/ head stable 2 trials
  - Acuity with head passively moved 15 degrees R to L @ 2 Hz
    - began @ 20/200 & continued until missed 3/5 optotypes on a given line
    - LogMAR of the line above the 'stop line' recorded.
    - Scores were averaged & calculated:
      - dynamic logMAR – static logMAR
  - ≥ .2 = positive test



Somatosensory Screen

- Light and deep touch, vibratory sense on leg;
- Position sense
- DTR's
- Hold against resistance (knee extend, ankle dorsi- and plantar flex)
- Motor Screen RAM

Testing Components for Children

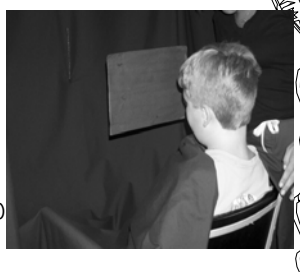
- Functional Abilities
- Postural control measures
- Vision & oculomotor testing, somatosensory/motor screening
- Vestibular testing

Vestibular Testing:

- Canals
  - Post-rotary nystagmus
  - Calorics, rotary
- Otoliths
  - SVV
  - VEMPS

Subjective Visual Vertical Testing

- Test protocol
  - Align bar, vision and somatosensory cues min/ eliminated
  - Cannot see or feel alignment
  - Vision blocked between trials
  - W/in 2 degrees normal (even as young as 4.5 yo)



L Farrell & RM Rine, CSM 2005

VEMP Testing

(vestibular evoked myogenic potential)

- Response of SCM to stimulus
  - Air: 95 dB nHL
  - Bone – 55-66 Hz
  - Latency (P13 N23), , amplitude (corrected to baseline)
- Adults and children 3-9 yrs
- Rep. Fx integrity of saccule or inf. vestibular nerve

Differential Diagnosis: (what if motor or vision?)

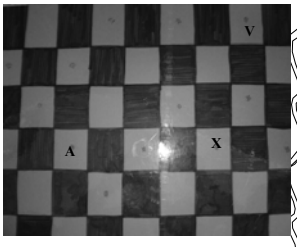
Tests:	Peripheral V	Central V	motor
Sensory	+	-	-
Motor synergy	- (+ for acute /B Ves)	+ or -	+ (weak,absent)
SOT	+ selective	+ 4-6	+ ALL
Vestib-nystagmus	+	-	-
Subjective	Spinning Dizzy; cannot walk	Not dizzy; ?off bal.; rx's delay; not safe	Not dizzy; cannot stay up, not off bal.

Evidence of reading acuity deficit:10 year old – Bilateral hypofunction

- Typical development to 1.5 yrs
  - Diabetic coma w/resultant hearing loss, VeD, no other functional loss.
  - Severe/profound SNHI (implant @ 3yrs)
  - No referral, struggle in school, parent fighting for mainstreaming
- Exam & Evaluation:
  - CN (not VIII), DTR, motor development negative
  - HT and HS positive bilaterally
  - DVA – 6.5 line difference
  - Reading acuity – below norm
- Intervention:
  - 18 sessions – 3X/wk for 6 wks
  - focus: improve visual system & substitution – visual focus w/head and/or target mov't

Intervention to Improve Gaze Stability

- Targets: letters & numbers - 20, 16 & 12 point
- Backgrounds: simple to complex
- Change size, speed, background complexity @ 80% criterion



Plan and Results -Improved Gaze Stability

- ABA design
- Improved CPS, RA, & DVA
  - DVA to 3.5 lines difference; reading signs while riding in car
  - Similar to adults, improved gaze stability fx w/intervention
  - ? Intensity vs duration

Braswell J, Rine RM *Pediatric Otorhinolaryngology*. 2006 70:1957-1967.

5 yo Child with VeD following severe MEF (? Neuritis)

- Male (AG) episodic right lean (w/falls) over 7 mos
  - Med Hx not significant for illness
  - Developmental: Prematurity w/complications: mild L sided hemiparesis @ 6 moa; PT & OT TIW x past 4 years; PT D/C'd – no gait deficits
    - Participated in soccer & basketball
    - Corrective sx for strabismus (5 surgeries)
- Neurology referral:
  - MRI's (head, neck & spine) = negative
  - Ruled out seizure, vision & other CNS factors
- Otolaryngology referral:
  - Severe bilateral middle ear infection. Rx: bilateral tube insertion; Post-op lean lessened, but full w/in 4 mos
  - Rotary & caloric tests deferred 2° to tube insertion;
  - PT referral - comprehensive vestibular assessment and Rx

5 yo – Examination (cont'd)

- **Ambulation:**
  - I, symmetrical no deviations; stop/unsteady walking around/over object

Oculomotor:
- OKN negative
- Sm Pursuit negative R, corrective saccades L
- Convergence intact.

Vestibular:
- HS negative
- HT positive L, negative R
- DVA positive (3.5 difference) During test, progressive lean to R and experienced LOB
- VEMP testing: normal R, reduced/absent L, AR 56%

Examination (cont'd)

- Posturography:
  - LOB conditions 5 & 6; stepping on 3 & 4
  - Within age norms on conditions 1 & 2
  - Delayed TA on dynamic test (step)
- Neuromuscular & Musculoskeletal :
  - Symmetrical gait, no evident hemiparesis.
  - ROM, DTR's strength negative.
  - Associated movements w/effort.
  - Proprioception: intact UE & LE's (identified & mirrored)
- Motor development: PDMS Gross Motor Scale: Reflex subtest 95%; total score @ 2nd percentile.
  - Deficits: Balance, Non-locomotor & Receipt and Propulsion : SLS < 5 sec ea leg, hop only 1x on either leg).

5 yo Evaluation Summary

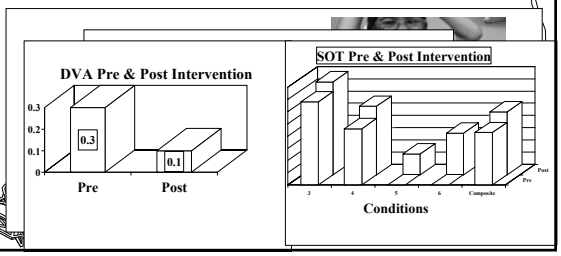
- Diminished GM & oculomotor function consequent to, or exacerbated by UP-VeD involving left horiz. canal and saccule.
- Possible central involvement due to prematurity; visual-motor/strabismus.
- Impairments include aberrant:
  - sensory organization for balance
  - use of vision & somatosensation for balance
  - verticality
  - oculomotor ability.

5 yo UP –VeD Intervention

- School modifications: modified seating (chair with arms @ proper seat height, enlarged print & aide). IEP adjusted accordingly.
- Home exercises: oculomotor, vision, somatosensory training; 4x/week.
- Direct PT : balance & oculomotor training provided 2x/wk for 3 months.

5 yo Rx Results

- Improved alignment w/self correction,
- Improved postural control (SOT)
- Improved DVA
- Improved GM skills
- Head thrust negative bilaterally



Vestibular Related Impairments in Children with OME

- Plan:
  - Recruited children with OME
    - Exclusion criteria: any known or identified musculoskeletal abnormalities of the legs or spine, neuromuscular disease/condition, diminished sensation of the legs, significantly impaired vision, or developmental delay
- Test vestibular function (pre & post sx)
    - Head thrust for canal, VEMP for otolith
  - Test Fx: motor development, postural control, dynamic visual acuity (pre and post-sx)

Central Hypothesis

- Children with chronic MEE or SNHI have concurrent vestibular dysfunction (VeD), which is reduced with tube insertion
- VeD in this groups results in impairments of gaze stabilization, balance and postural control

Results – Pre-test

- Vestibular tests
  - Positive HT tests, bilaterally
  - Positive air VEMP bilaterally
- Posturography
  - All above the 75th percentile conditions 1-3
  - All below the 50th percentile conditions 4-6
- PDMS II
  - All below the 50th percentile & scored significantly below the norm ($p \leq .05$) on the stationary and object manipulation subtests.
- DVA – 1 child refused, all others had positive tests

Post- testing

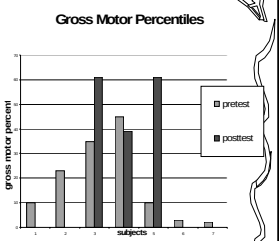
- Vestibular tests
  - All negative head thrusts post sx
  - All negative air VEMP post sx

Subjects	Head Thrust Pre	Head Thrust Post	VEMP air Pre	VEMP air Post	VEMP bone pre	VEMP bone post
NOMEJ001		NT	NT	NT	NT	NT
NOMEJ002	+ +	NT	–	NT	–	NT
NOMEJ003	+ on right	–	+ +	– (*)	–	–
NOMEJ004	+ +	–	+ +		–	
NOMEJ005	+ +	–	+ +	– (*)	–	–
NOMEJ008			+ +		–	

NT = Subject was not tested
+ = Positive abnormal test result
– = Negative normal test result
+ + = Positive test result bilaterally
(*) = although the VEMP response is present, the child scores were significantly lower than their aged norm peers.

Post Tests – PDMS-II

- Two improved to above the 60th percentile
- T-test results support that improvement was significant: stationary and object manipulation p = .05; locomotion p=.12.
- Due to small sample size, power limitations affect these results.

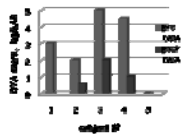


Post- test DVA

- Two of three children had improved gaze stability scores to within normal limits.
- The lack of improvement in score for one child may be attributed to this being his third set of tubes.

Subjects	DVA Pre	DVA Post
NOMEJ001	NTA	NT-LTF
NOMEJ002	+	NT-LTF
NOMEJ003	+	+
NOMEJ004	+	-
NOMEJ005	+	-

DVA Pre- and Posst Sx



Conclusion: In children w/OME

- Significant deficits of motor development, dynamic visual acuity and postural control
- Sx intervention improves status, but to norm
- Suggests need to examine efficacy of physical therapy intervention
- Additional study is needed to
  - Increase # tested
  - Compare to control group of OM recurrent

Study supported by UNF Brooks Professorship & Nemours Children's Clinic

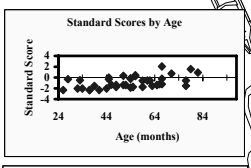
Effect of Exercise Intervention on Motor & Postural Control of Children with vestibular hypofunction

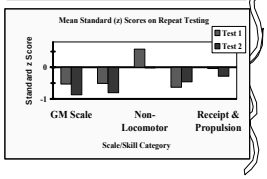
- **Subjects:**
  - 24 children with SNHI since birth
  - Exclusion: cognitive, orthopedic or other neurological impairment
  - Screening: DTR's, cranial nerve, coordination and vision
  - Random assignment to 1 of 2 groups
    - matched for vestibular function & motor development level

Supported by NIH grant # HD37820-02 and Foundation for Physical Therapy

Impairments related to bilateral vestibular hypofunction

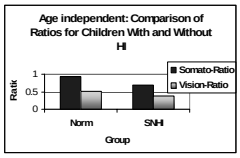
- 2.5-8.5 yoa w/SNHI
- delays on gross motor abilities ($p < .03$); less w/age
- Longitudinal testing: z scores lower ($p < .05$)
- Sensitivity of PRNT for identification of progressive deficit = excellent (91%)

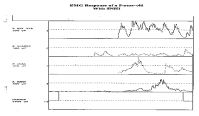




Perceptual & Motor Skills. **2000. 90:1101-1112**
Pediatric Physical Therapy 1998. 10:16-23

Postural Control Deficits





- **Lower on SCT-3, -4 ($p < .04$), vision and somatosensory ratios ($p < .05$)**
- **Increased latency & amplitude of TA ($p = .04$)**
- **Altered relative latency of soleus and TA ($p = .05$)**

Control of Posture and Gait. 2001. 40-45.

Study Methods:

- **Controlled, wait-listed design**
- **Pre- and post-intervention tests of motor development & postural control**
- **Intervention:**
  - **Exercise 12 weeks – placebo 12 weeks = EP**
  - **Placebo 12 weeks – exercise 12 weeks = PE**

****Testers - blinded to group placement**

****Test 1 –intervention – Test 2 -- intervention – Test 3**

Intervention

- **Under direction of PT, by aide**
  - **3 x weekly, small groups (2-3)**
  - **PT – weekly review, advance activities prn**
- **Activities to facilitate:**
  - **Vision and somatosensory function**
  - **Substitution**
  - **Learning**

Balance Training:

- **Proprioceptive training, and balance –**
  - **Different postures**
  - **Different surface compliance**
- **Ex: scooter board, thick mat, tandem walk on busy surface**

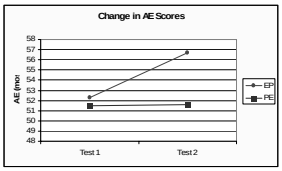
Visual –motor training

- Adaptation & habituation: vestibular rehab
- Visual stabilization w/head and/or object movement
- Increase complexity of object, background
- Ex: Swing, sway boards, pics on balloons

Eye Hand Coordination:

- Eye-hand or –foot
- Varying target size, shape, distance
- Varying postural demands
- Ex: balloon badminton, target games

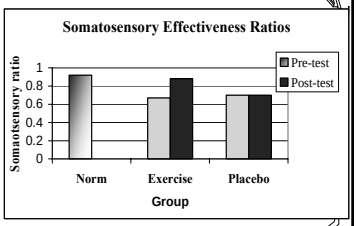
Results: Test 2 (post-intervention)



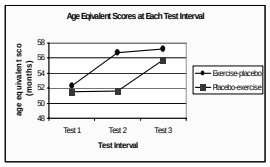
- Improvement of motor development (EP not PE group)
  - Raw scores (p < .04) all subtests
  - AE scores – previously similar, now differ

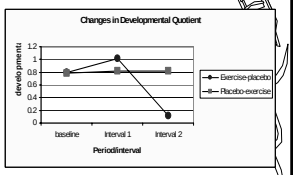
Results: Test 2 (post-intervention)

- **Improved sensory organization** (EP not PE group)
  - somatosensory (p = .01)
  - Like normative sample!
- DPT: strategies not changed



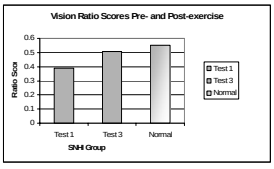
Results: Test 3 (post-intervention)

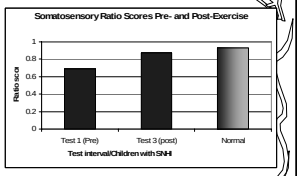




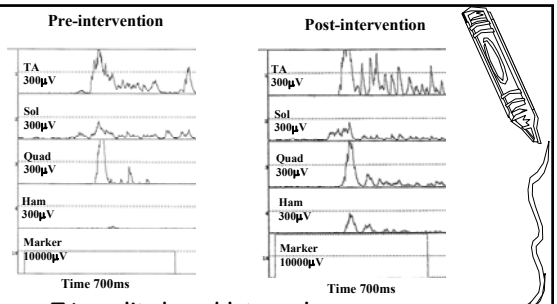
- Motor Development – PE not EP improved (p = .01)
  - Gain reversal of AE
- Developmental quotients altered (p = .01)
  = AE pre-test/ chronological age @ pre-test versus post-test

Results: Test 3 (cont'd)





- SCT gains, continued for both (combine scores)
  - Vision & somatosensory ratios improved (p < .04) and like normative sample



- TA amplitude and latency larger
- Falls/steps 21 (85%) pre, only 4 (16%) post
- New alternative strategy: previously inactive hamstrings activated

Results:

- Before and after DPT
- Vestibular function
  - No relationship

Discussion

- Exercise intervention :
  - improved function, related to improved sensory organization & alternative postural strategies
- At withdrawal of exercise – reversal
  - Increased intensity vs duration
  - Require practice, error correction and pre-cursor skills established
- Lack of relationship w/vestibular test :
  - Limitation of testing – omitted otolith test (related to acquisition of walking in norms)

Rine RM Braswell J *Pediatric Otorhinolaryngology 2004*

Known and Unknown?

- **Know:**
  - Children have vestibular & balance deficits w/consequent impairments in vision and motor abilities
    - Need intervention
  - DVA and posturography testing good tests to identify deficits
    - Assist in directing intervention
  - Intervention improves vision and motor abilities
  - FOCUS INTERVENTION on appropriate mechanism!!
- **Unknown:**
  - Incidence of vestibular or balance impairments in children with CNS deficits; babies in NICU
  - Simple testing of vestibular & posturography in children less than 3 yrs.
  - Normative data on posturography: EMG, ankle vs hip strategy, dynamic limits of stability
  - Relationship of posturography scores and functional testing in children