Motion Analysis in Understanding Movement Pathology in Myelomeningocele
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Disclosure Information
AACPDM 69th Annual Meeting | October 21-24, 2015

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Disclosure of Relevant Financial Relationships
We have no financial relationships to disclose.

Disclosure of Off-Label and/or investigative uses:
We will not discuss off label use and/or investigational use in my presentation

Outline:
- Common gait deviations of individuals with myelomeningocele
- Linking gait deviations to treatment: surgical, bracing and assistive devices using motion analysis
- Case studies – bracing and surgical (using gait analysis)
- New Frontiers - using motion analysis to optimize wheelchair propulsion in patients with myelomeningocele
Neural tube defects

- Congenital malformation secondary to lack of closure of neural tube
- Incidence 1-10/1000
- Anencephaly
- Spina bifida

Spina Bifida

- Myelomeningocele, meningocele, lipomeningocele
- Myelomeningocele >90%
  - protrusion of neural tissue and its covering through a defect in the vertebrae
  - ~2/10000 live births

Each year, about 1,500 babies are born with spina bifida in US

- Hispanic: 4.17 per 10,000
- Non-Hispanic Black or African-American: 2.64 per 1000
- Non-Hispanic White: 3.22 per 10,000

CDC - CENTERS FOR DISEASE CONTROL AND PREVENTION
The etiology is not well understood, complex, multifactorial

- Maternal folic acid status is critical for proper neural tube closure, 1991
  - U.S. Public Health Service recommended 400 micrograms folic acid daily 1992
  - FDA mandated fortification of food products, January 1996
  - Prevalence in USA decreased 31% from pre-fortification to post-fortification
    - Centers For Disease Prevention and Control

Spina Bifida

- 1960s advances in medical care led to the survival of majority of individuals
  - 10% infant death rate
  - 75-85% are expected to reach early adult years
  - Long term disability

- The mortality, disability and achievement reflected the neurological level
  - One-third needed daily care, while 30-40% lived independently
  - There is lack of comprehensive and lifelong care available to the adult
  - The death rate from age 5 to 40 years is 10 times the national average
  - Late deterioration is common
Social support and parental hope are more strongly associated with self-worth and health-related quality of life than gender, age, diagnosis, or physical impairment.

Mobility is an important determinant of quality of life for those with Spina Bifida (SB).

Perceived HRQOL of young adults with SB is lower, especially within the physical functioning domain.

The ultimate walking ability of the patients with Spina Bifida depends on many factors of which the most important is the extent of the neurological deficit.

Children with similar level of motor paresis do not always develop similar ambulatory levels:

- Negative factors:
  - Balance disturbances
  - Multiple shunt revisions
  - Spasticity
  - Knee and hip joint contractures
  - Hip dislocation was not
Gait Analysis has radically changed the treatment of cerebral palsy

- Assessment of patient’s pathology before and after treatment

Could the same principles of gait analysis (treatment based on the objective assessment) be applied to the patients with Spina Bifida?

Gait Analysis and Spina Bifida

- Objective analysis of gait plays a fundamental role in the assessment of both the functional limitation and the outcome of the treatment
Gait Analysis and Spina Bifida

• Gait patterns
• Assessment and treatment
• Effectiveness of orthoses & assistive devices

GCMAS Symposium at the AACPDM, October 21, 2015

Part 3: Myelomeningocele

Gait Patterns

Gait Patterns
Kinematics

• Persistent dorsiflexion due to plantar flexor weakness led to more flexed position at knees and hips and anterior tilt of the pelvis

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Part 3: Myelomeningocele
Gait Patterns

Kinematics

- Hip abductor weakness
- Produces the largest change in gait strategy
  - Trunk and pelvic rotation
  - Large lateral trunk sway
  - Hip abduction during stance
  - Pelvic hike
  - In this gait pattern, energy transferred from hips down into the lower extremities

Gutierrez et al, Gait and Posture 2003

Pelvis tilt and hip flexion is increased
Weak hip extensors
Hip flexors are used to initiate gait in the absence of plantar flexors
Pelvic obliquity is increased
Lateral sway of the body over the stance phase
"Trendelenburg gait" helps to elevate the pelvis on swing side and hike the swing limb forward
Pelvic rotation
Internal rotation is increased at initial contact as a result of "hiking" the swing limb forward
Hip abducted at initial contact and remains abducted over the stance phase

Kinetics

Valgus Knee Stress

<table>
<thead>
<tr>
<th>Valgus Knee Moment</th>
<th>25%</th>
<th>50%</th>
<th>75%</th>
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<tbody>
<tr>
<td>Nm/kg</td>
<td>1.0</td>
<td>-1.0</td>
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</table>

Valgus Knee Stress
Management of hip disorders had undergone a radical change over the years.

"It was not possible to determine whether or not the patients would have been able to walk without iliopsoas transplantation, or a similar operation as there were no controls."
• 16 transplants in 13 patients
• EMG activity is recorded for active hip flexion, abduction, extension and passive flexion
  - All transplants: Active in active flexion but not in passive, some activity during abduction, very minimal activity with extension
  - “it is doubtful if it acts as a true glutal replacement or that independent abduction and extension are readily achieved”

• 28 patients
• 10 patients with L4 level, all had reduced hips
• No difference in the range of pelvic obliquity between those who had posterolateral transfer of the iliopsoas to greater trochanter and who had not
• Range of hip adduction/abduction and rotation was significantly worse

“Abductor limp is not eliminated, but lessened, self reported substantial increase in sense of security”
28 hips, L3-4 to S1
- 85.5% active in swing phase
- 69.2% during toe-off
- 46% during stance phase
- 93% of the time the muscle functioning during the gait cycle as a hip abductor, it is phasic

CASE PRESENTATION

Gait Analysis in Low Lumbosacral Myelomeningocele Pattern With Unilateral Hip Dislocation or Dislocation

Gait symmetry corresponded to the absence of hip contractures and had no relation to the presence of hip dislocation
A level pelvis and a good range of motion were found to be more important for function than reduction of the hip.

Ambulation in Patients with Myelomeningocele: A Multivariate Statistical Analysis

A pelvic obliquity and hip dislocation did not affect the ambulatory status when analyzed together with scoliosis, age and neurological level.

Assessment and Treatment
KNEE

72 patients-lumbo-sacral- community ambulators, 24% did have knee symptoms of
- pain,
- instability with activity

Selber and Dias, 23%, JPO, 18, 1998

Valgus Knee Stress

Coronal plane valgus knee stress is multifactorial and trunk motion and external tibial torsion are major contributors.
Valgus Knee Stress

CASE VIDEO

Crouch Gait

- STATIC CLINICAL EXAM MAY NOT ALWAYS REFLECT THE ACTUAL FUNCTIONAL STATUS OF THESE PATIENTS
Crouch Gait

Pelvic Tilt
50° -10°
Ant Post deg
25% 50% 75%

Hip Flexion/Extension
90° -20°
Flex Ext deg
25% 50% 75%

Knee Flexion/Extension
75° -15°
Flex Ext deg
25% 50% 75%

Foot Dorsi/Plantar
40° -80°
Dors Plan deg
25% 50% 75%

Down deg
Add Abd deg

Tibial Torsion

- EXCESSIVE INTERNAL /EXTERNAL TIBIAL ROTATION
- Tripping, poor balance and difficulty with gait
- Poor fitting with the brace, pressure sore
- Valgus knee stress
- Diminished effectiveness of the solid ankle foot orthosis
Tibial Torsion

- Patients with external tibial rotation deformity on the order of magnitude around 20° or greater who fail to demonstrate improved knee extension moments may benefit from correction of their increased tibial torsion

Tibial Torsion

- Significant improvement in the abnormal internal knee varus moment as well as significant increase in the stance phase knee extension

Part 3: Myelomeningocele
CASE VIDEO

Assessment and Treatment
Calcaneal Foot Deformity

Anterior Tibial Transfer to the Os Calcis with Achilles Lengthening for Calcaneal Deformity in Myelomeningocele

Surgical Treatment of Calcaneal Deformity in a Select Group of Patients with Myelomeningocele
Assessment and Treatment
Calcaneal Foot Deformity

Pre – Post Peabody Transfer: Pedobarography

Part 3: Myelomeningocele
Effectiveness of Orthoses and Assistive Devices

- With respect to barefoot conditions, the use of AFOs leads to an improvement in gait and reduced energy consumption.

L4–L5 patient group
- Improved ankle and knee sagittal plane function
- Reduction in excessive ankle dorsiflexion
- Decreased peak plantar flexor moment
- Reduction in crouch and knee extensor moment

Sacral patient group
- Diminished power generation pre-swing

All groups
- Increase in transverse plane knee rotation (was normal with sacral group barefoot)

Improvements in brace construction and design with stronger and lighter energy-storing materials can result in improved ambulation.

Carbon fiber spring orthosis
- Improves ankle plantar flexion moment
- Increases ankle positive work
- Increases stride length
- Increases energy return during the 3rd rocker, simulating the natural push-off action
Crutches alleviate weight bearing on the lower extremities, decrease exaggerated pelvic and hip compensatory kinematic movements and help facilitate forward progression.

The maximum stresses during swing through gait were found to be significantly greater than those during reciprocal gait.

New Frontiers - using motion analysis to optimize wheelchair propulsion in patients with myelomeningocele.
Shoulder Pain for Individuals with Spina Bifida (Roehrig and Like, 2008)

- 30%-41% of individuals diagnosed with spina bifida reported shoulder pain related to manual wheelchair propulsion
- Individuals older than 18 years-old had greater pain than those between ten and eighteen year of age.

Optimal 2-D Pushrim Kinematics

- Optimal Motion: Semicircular Pattern
  - Users hit the pushrim less frequently and used more of the pushrim to go the same speed.

Hurdles to Motor Learning

- Learning novel tasks can be difficult for individuals with Spina Bifida due to high prevalence of impaired:
  - Sustained attention (Castersen and Habekost, 2013)
  - Executive function (Tuminello, 2012)
  - Intrinsic motivation (Tuminello, 2012)
  - Upper limb functional deficits (Dennis, 2009)
    - Arm posture and rebound
    - Finger–nose–finger
    - Rapidly alternating hand movements
Propulsive Training with Augmentative Visual Feedback

- During skill acquisition, children who received constant augmentative visual feedback during training performed a novel task with greater accuracy and consistency than children who received reduced feedback during practice.

Wheelchair
Dynamometer
Visual Display
Passive
Markers

Training with Augmentative Feedback
Pre – Post Comparison

<table>
<thead>
<tr>
<th>Value</th>
<th>Pre</th>
<th>Post</th>
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<tbody>
<tr>
<td>Average Speed (m/s)</td>
<td>1.2</td>
<td>1.4</td>
</tr>
<tr>
<td>Push Frequency (contacts/second)</td>
<td>0.9</td>
<td>0.8</td>
</tr>
<tr>
<td>Push Length (degrees)</td>
<td>67.2</td>
<td>78.0</td>
</tr>
<tr>
<td>Weight-Normalized Force (% body weight)</td>
<td>5.2</td>
<td>7.5</td>
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Acknowledgements

- Shriners Hospitals for Children:
  - Adam Graf, MS
  - Gerald F. Harris, Ph.D., PE

Thank you!