Pediatric Spinal Cord Injury Lifelong Outcomes

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Unique Features of Spinal Cord Injuries in Children and Adolescents

• Uniqueness of pediatric SCI is based upon:
  – the dynamic nature of growth and development in children and adolescents
  – the mutual interactions of growth & development with the manifestations & complications
Uniqueness of Pediatric SCI

• Children who sustain a SCI have a relatively long-lifespan
  – Susceptible to secondary health conditions over a longer period of time compared to adult-onset SCI
    • Premature aging
    • Live with secondary health conditions for a longer time
  – Children are also susceptible to unique complications
Uniqueness of Pediatric SCI

- Children are not small adults
- Must take into account growth & development from infancy through adolescence into adulthood
  - Physical
  - Physiological
  - Psychological
  - Cognitive
Developmental Considerations

Physical

- Size
  - Weight
  - Physical size
  - Bladder volume
- Neuro-Musculoskeletal
  - Linear growth
    - Scoliosis
Developmental Considerations
Physiological

- Heart rate
- Blood pressure
- Bowel and bladder function
A SCI impacts/interacts with all the psychological changes characteristic of each developmental stage.
Developmental Considerations

Cognitive

Ability to communicate
- Symptoms of autonomic dysreflexia
- Expression of pain

Ability to learn/understand
- Self-catheterization
- Pressure ulcer prevention

Reasoning
Manifestations of SCI that are a consequence of young age

- SCIWORA = spinal cord injury without radiologic abnormalities
- Delayed onset of neurologic deficit
Complications of SCI related to young age at time of injury

- Hypercalcemia
- Scoliosis
- Hip subluxation and contractures
Incidence

Overall = 40 cases/1,000,000 or 10,000 new cases/year

<15 years of age  3-5% of SCIs
<20 years of age  20% of SCIs
## Gender

<table>
<thead>
<tr>
<th>Age Group</th>
<th>Male</th>
<th>Female</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-5 years</td>
<td>51%</td>
<td>49%</td>
</tr>
<tr>
<td>6-12 years</td>
<td>58%</td>
<td>42%</td>
</tr>
<tr>
<td>13-15 years</td>
<td>69%</td>
<td>31%</td>
</tr>
<tr>
<td>16-21 years</td>
<td>83%</td>
<td>17%</td>
</tr>
<tr>
<td>22+</td>
<td>81%</td>
<td>19%</td>
</tr>
<tr>
<td>Etiology</td>
<td>0-5 yrs</td>
<td>6-12 yrs</td>
</tr>
<tr>
<td>----------</td>
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<td>----------</td>
</tr>
<tr>
<td>MVI</td>
<td>60%</td>
<td>57%</td>
</tr>
<tr>
<td>Violence</td>
<td>5%</td>
<td>3.7%</td>
</tr>
<tr>
<td>Sports</td>
<td>0%</td>
<td>9.4%</td>
</tr>
<tr>
<td>Falls</td>
<td>7.5%</td>
<td>7.5%</td>
</tr>
<tr>
<td>Med/surg</td>
<td>16.3%</td>
<td>18.7%</td>
</tr>
<tr>
<td>Other</td>
<td>11.2%</td>
<td>3.7%</td>
</tr>
</tbody>
</table>
Etiologies unique to pediatric SCI

• Lap-belt
• Birth injury
• Fibrocartilagenous emboli
• Transverse myelitis
• Acute flaccid paralysis
• High cervical lesions
  – Downs
  – Skeletal dysplasias
  – JRA
Transverse myelitis

- Diagnosis requires:
  - Spinal cord inflammation
    - CSF pleocytosis
    - ↑ CSF IgG
    - Gadolininium enhancement on spinal MRI
    - Absence of CSF infection
- Bimodal distribution in peds:
  - One peak in toddlers <3 years of age
  - Second peak 11-17 years of age
Transverse myelitis

- Better prognosis
  - Older age of onset
  - Shorter time to dx
  - Lower neurological level
  - Absence of T1 hypointensity acutely
  - Lack of CSF pleocytosis
  - Fewer affected segments
Transverse myelitis

• Prognosis
  – 1/3 completely recover
  – 1/3 some improvement but residual deficits
  – 1/3 have little to no improvement
Acute flaccid paralysis

- Acute flaccid myelitis
- Guillain Barre
- Toxic neuropathy
Acute flaccid myelitis

- Sudden weakness in one or more arms or legs
- Decreased muscle tone or absent reflexes
- Occasional involvement of cranial nerves
  - Facial weakness
  - Swallowing difficulties
  - Drooping of eyes
Acute flaccid myelitis

Confirmed case
• Acute onset of focal limb weakness AND
• MRI
  – Largely restricted to gray matter
  – Spanning one or more spinal segments

Probable case
• Acute onset of focal limb weakness AND
• CSF with pleocytosis
Acute flaccid myelitis

Etiologies

• Enterovirus D68
• West Nile virus
• Herpes
Acute flaccid myelitis

Clinical presentation
• Acute onset of asymmetric limb weakness
Median age=7.6 years (5 months – 20 years)

Prognosis
• 2/3 some improvement
• 1/3 no improvement
• No one fully recovered
Fibrocartilagenous emboli

Acute vertical disk herniation ➔
Retrograde embolization of nucleus pulposus ➔
Vasculature supplying the anterior spinal cord ➔
Spinal cord infarct

• Rapid onset of weakness after sudden onset of severe pain
• May be precipitated by physical exertion
## Neurological Impairment versus Age at Injury

<table>
<thead>
<tr>
<th>Age Group</th>
<th>Para</th>
<th>Tetra</th>
<th>Complete</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-5 years</td>
<td>55%</td>
<td>45%</td>
<td>80.7%</td>
</tr>
<tr>
<td>6-12 years</td>
<td>62.5%</td>
<td>36.5%</td>
<td>68.4%</td>
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<tr>
<td>13-15 years</td>
<td>47.6%</td>
<td>51.9%</td>
<td>55.6%</td>
</tr>
<tr>
<td>16-21 years</td>
<td>46.8%</td>
<td>52.9%</td>
<td>56.8%</td>
</tr>
<tr>
<td>22+ years</td>
<td>39%</td>
<td>60.3%</td>
<td>39.1%</td>
</tr>
</tbody>
</table>
Neurological Impairment versus Age at Injury

- Limitations of ISNCSCI in children
  - Especially in children ≤ 5 years of age
  - Safety pin and children’s reaction
  - Discriminate sharp and dull
  - Validity of anorectal examination
    - Voluntary anal contraction

SCIWORA = Spinal Cord Injury WithOut Radiologic Abnormality

SCI without evidence of fracture or dislocation on:

- Routine spine radiographs
- Tomography
- CT
- Myelography
- Dynamic flexion/extension studies
SCIWORA

0-5 years        64.2%
6-12 years       32.5%
13-15 years      22.3%
16-21 years      19.5%
Spine deformity

- **Etiology**
  - Muscle weakness/imbalance
  - Residual spine deformity following fracture
  - Iatrogenic: laminectomy
### Prevalence of Scoliosis

**Dependent upon age at time of injury**

<table>
<thead>
<tr>
<th></th>
<th>Prior to puberty</th>
<th>After puberty</th>
</tr>
</thead>
<tbody>
<tr>
<td>Prevalence of Scoliosis</td>
<td>98%</td>
<td>20%</td>
</tr>
<tr>
<td>Need for surgery</td>
<td>67%</td>
<td>5%</td>
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</tbody>
</table>
Hip Subluxation/Dislocation

- Incidence = 30-40%
  - More common in children who are younger when injured

<table>
<thead>
<tr>
<th>Age when injured</th>
<th>Incidence of hip instability</th>
</tr>
</thead>
<tbody>
<tr>
<td>≤8 years</td>
<td>62%</td>
</tr>
<tr>
<td>≥9 years</td>
<td>10%</td>
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</tbody>
</table>
The ultimate measures of success in caring for youth with SCI

Optimal participation and satisfaction as they progress through childhood and adolescence

Bottom line
They become adults with productive and satisfying lives
Goals for adults with pediatric-onset SCI

- Healthy
  - Physical
  - Emotional
- Independent
  - Living
  - Mobility
  - Autonomy
- Employed
- Participate fully in their communities
- Satisfying lives
Challenges in caring for the child with a spinal cord injury

• Establish goals that evolve as the child matures and ultimately becomes an adult
  – Establish a sound foundation for a successful transition into adulthood that lasts a life-time

• Prevent complications

• Maintain focus on the big picture full participation and satisfying life

• Both innovative and standard interventions must support this overarching goal
Challenges in caring for the child with a spinal cord injury

- Need to have outcome measures that accurately assess key outcomes from injury as a child throughout adulthood
- Solid understanding of the natural history of pediatric SCI throughout their lifespan
- Identify risk factors for suboptimal outcomes throughout their lifespan
Outcome Instruments

- Few instruments with psychometric support for children with SCI
- Difficulty in assessing outcomes and determining treatment effectiveness
- Priority for pediatric SCI rehabilitation
  - Establishing psychometric properties of existing tools
  - Developing and validating new tools, meaningful to children
  - Develop measures that cover the lifespan
Pediatric SCI Instrument: Computer Adaptive Tests

- Large item banks of mobility, activity and participation (Calhoun et al)
- Filter questions
  - Sex, age, use of equipment, type of chair
- Computer adaptive tests and short forms
- Linked with adult SCI CAT and short forms

Mulcahey et al 2012; Bent et al 2013; Tian et al 2014
Pediatric SCI Instrument: Pediatric Neurorecovery Scale

Behrman A, Mulcahey MJ, Ardolino E Craig H. Neilsen Foundation. Award Number: 260284

Neuromuscular Recovery Scale for Pediatric Spinal Cord Injury
Common Data Elements

- NINDS
- SCI CDEs
  - Pediatric modifications
International SCI datasets

- Need pediatric modifications
- Examples
  - Etiology
    - Birth injury
  - Bowel, bladder and sexual functioning
Profound change in our approach to rehabilitation & its goals

- A more comprehensive approach with incorporation of disability model
- Outcomes and different spheres of life
- The time-line
  - The lifespan
  - Developmental stages
Outcomes

- Education
- Employment/Occupation
- Living independently
- Mobility
- Participation
- Social development
- Sexuality
- Psychological functioning
- Health/Wellness
- Quality of life
WHO International Classification of Functioning, Disability, and Health (ICF) Model

Health Condition

SCI

Body Function & Structure
- Paralysis
- Pressure ulcer
- Depression

Activity

Participation

Environmental Factors

Personal Factors

Quality of Life
Focus has changed from fixing impairments to focusing on participation and life-satisfaction

- Walking $\rightarrow$ Mobility
  - Full participation in school and community throughout the lifespan
Mobility versus Walking

Mobility is a critical factor that facilitates activity and participation

• The mobility modality must accomplish the task at hand
  – Efficient
  – Independent
  – Cosmetic
  – Socially acceptable

• Mobility for the entire lifespan
  – Issues of aging
    • Preservation of function
    • Prevention of complications
Walking

• Walking is integrated into a comprehensive rehab program where the goal is participation and life satisfaction versus “Walking" as the sole goal versus

• Walking versus the wheelchair
  – Is it one or the other?
Mobility
More Comprehensive Goals

- Ambulation
- Standing
- Wheelchairs
- Community
- The electronic world
Changes need to be viewed as transitions and not as failures

Transition of school-aged child from ambulation with orthotics to wheelchair
Orthotics and Assistive Devices

- Traditional orthotics
  - AFOs to RGOs
  - Standers

- Assistive devices
  - Walkers
  - Forearm crutches
Exoskeletons
Activity-Based Rehab
Locomotor Training

• Step Training using Body Weight Support on a Treadmill (BWST) and manual assistance
• Robot-assisted walking therapy
• Incomplete SCI
Walking Pitfalls

- Long-term complications
  - Upper extremity from assistive devices
  - Lower extremity from joint instability
- Guilt or sense of failure
  - Child/adolescent or parent
  - Failure to pursue “innovative programs”
  - Failure to continue to ambulate
  - Utilization of wheeled mobility
Mobility - More Comprehensive Goals

Wheelchairs

– Advances in wheelchair design
  • Ultra-light weight
  • Power assist
  • Advances in power chairs
– Upper extremity preservation
– Seating systems & pressure mapping
– Power versus manual
Mobility: More Comprehensive Goals

Community mobility
– Motor vehicles
– Public transportation
– The great outdoors
Went from fixing impairments to focusing on participation and life-satisfaction

• UE interventions → Self-catheterization
Continent Catheterizable Urinary Conduits
Upper Extremity Reconstruction
Psychosocial Outcomes

- Youth seem to be developmentally appropriate in terms of the content of their participation.
- Youth seem to have lower levels of participation and quality of life ratings than typically developing youth.
Psychosocial Outcomes

- Mobility and participation and quality of life of youth with SCI

- Ability to enter/exit independently was related to:
  - Participating in more informal activities
  - Participating in informal activities more often
  - Greater emotional, social, and psychosocial quality of life
Sexuality

• Issues common with all youth
  – Sexual development, functioning, and STDs
• Issues common for youth with all special needs
  – Self-esteem
• Disorder-specific issues
  – Sexual functioning
  – Fertility
  – Genetics
Caregivers

- Caregivers are critical to the well-being of youth with SCI
- The toll of caregiving
  - Physical
  - Emotional
  - 20% of caregivers reported experiencing moderate or severe anxiety
  - 22% moderate or severe depression
Caregivers

- Direct relationships between caregiver education, mental health, burden, and problem solving & mental health and quality of life of youth with SCI
- Caregivers having **more formal education** is related to:
  - Fewer symptoms of anxiety & depression among youth
  - Youth participating in more formal activities and experiencing greater enjoyment in formal activities
Caregivers

Increased caregiver anxiety & depression are related to:
• Decreased child psychosocial HRQOL
• Increased child anxiety and depression

Increased caregiver burden is related to:
• decreased child psychosocial HRQOL

More effective problem solving is related to:
• increased child psychosocial and physical HRQOL

Caregiver mental health influences how caregivers report about their child’s outcomes
Approach shifted from emphasis on short-term goals to long-term goals

Our management plan expanded to a grander time-span → the entire lifespan

• Transition
• Issues of aging
  – Preservation of function
  – Prevention of complications
Transition for youth with SCI Challenges

- Challenges common to all youth
- Challenges common to most diagnostic groups
  - Environmental barriers
    - Physical
    - Attitudinal
- Disease/disorder specific
  - Physical
- Youth/Family specific
  - Personal factors
  - Socio-cultural
Goals for adults with pediatric-onset SCI

• Healthy
  – Physical
  – Emotional
• Independent
  – Living
  – Mobility
  – Autonomy
• Employed
• Participate fully in their communities
• Satisfying lives
The ultimate measures of success in caring for youth with spinal cord injuries

Optimal participation and satisfaction as they progress through childhood and adolescence

Bottom line
As adults they will lead productive and satisfying lives
Dynamic nature of growth and development throughout lifespan adds an additional dimension to the ICF

- Infants
- Toddlers
- Preschool-aged child
- School-aged child
- Early adolescence
- Late adolescence
- Emerging adults
- Adults
- Aging adults
What is an emerging adult?

• 18-25 year olders
• No man’s land between the care-free adolescent and the adult with responsibilities
  – Job
  – Mortgage
  – Family
• May be the most tumultuous period of life after birth
A developmental perspective of the ICF model

<table>
<thead>
<tr>
<th>Age Group</th>
<th>Mobility</th>
<th>Employment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Infant</td>
<td>Stroller / car seat</td>
<td></td>
</tr>
<tr>
<td>Toddler</td>
<td>Walking</td>
<td></td>
</tr>
<tr>
<td>Preschool</td>
<td>Walking / tricycle</td>
<td>+/- Chores</td>
</tr>
<tr>
<td>School-aged</td>
<td>Walking / bike</td>
<td>Chores/ Neighborhood jobs</td>
</tr>
<tr>
<td>Early adolescence</td>
<td>Walking / public transportation</td>
<td>Neighborhood jobs</td>
</tr>
<tr>
<td>Late adolescence</td>
<td>Motor vehicles</td>
<td>Community-based jobs</td>
</tr>
<tr>
<td>Emerging adult</td>
<td>Planes, trains &amp; automobiles</td>
<td>Summer jobs First real job</td>
</tr>
<tr>
<td>Adult</td>
<td>Planes, trains &amp; automobiles</td>
<td>Real jobs</td>
</tr>
<tr>
<td>Older adult</td>
<td>Loss of independent wheeled mobility</td>
<td>Retirement Volunteer</td>
</tr>
</tbody>
</table>
A developmental perspective of the ICF model

<table>
<thead>
<tr>
<th>Age Group</th>
<th>Participation/Socialization</th>
<th>Where</th>
</tr>
</thead>
<tbody>
<tr>
<td>Infant</td>
<td>Family</td>
<td>Home</td>
</tr>
<tr>
<td>Toddler</td>
<td>Playgroups</td>
<td>Home</td>
</tr>
<tr>
<td>Preschool</td>
<td>Playgroups</td>
<td>Neighborhood centers</td>
</tr>
<tr>
<td>School-aged</td>
<td>Sports and Scouts</td>
<td>Neighborhood</td>
</tr>
<tr>
<td>Early adolescence</td>
<td>Sports &amp; hanging out</td>
<td>Community</td>
</tr>
<tr>
<td>Late adolescence</td>
<td>Dating &amp; hanging out</td>
<td>Community &amp; beyond</td>
</tr>
<tr>
<td>Emerging adult</td>
<td>Partying</td>
<td>Community &amp; beyond</td>
</tr>
<tr>
<td>Adult</td>
<td>Marriage</td>
<td>Community &amp; beyond</td>
</tr>
<tr>
<td>Older adult</td>
<td>Senior citizen groups</td>
<td>Community</td>
</tr>
</tbody>
</table>
How can we improve transition for youth with special needs

• Understand the natural history of youth with specific disabilities

• Evaluate factors associated with good and not-such good outcomes
  – Develop specific interventions when feasible
  – Target high risk groups for interventions
Long-term Outcomes of Pediatric SCI

- Caroline J Anderson, PhD
- Kathy Zebracki, PhD
- Kathy M Chlan
Long-term Outcomes of Pediatric SCI

• Identify long-term outcomes of adults with pediatric-onset SCI
  – Independent living and driving
  – Employment
  – Participation
  – Medical complications
  – Mental health
  – Quality of Life

• Identify factors associated with these outcomes
  – Demographics, impairment factors
  – Environmental factors
Participants

- 466 adults who sustained their SCI ≤ 18 y/o
- 63% males
- 54% tetraplegia
- 70% with AIS A
- Age of injury, mean = 13.9 (0-18)
- Age at follow-up, mean = 30.5 (24-45)
- Duration of injury, mean = 16.2 (6-38)
# Long-term Outcomes of Pediatric SCI

<table>
<thead>
<tr>
<th>Category</th>
<th>SCI</th>
<th>Census</th>
</tr>
</thead>
<tbody>
<tr>
<td>College education</td>
<td>40%</td>
<td>32%</td>
</tr>
<tr>
<td>Employed</td>
<td>60%</td>
<td>90%</td>
</tr>
<tr>
<td>Married</td>
<td>21%</td>
<td>41-65%</td>
</tr>
<tr>
<td>Live independently</td>
<td>64%</td>
<td>88%</td>
</tr>
</tbody>
</table>
Long-term Outcomes of Pediatric SCI

- Pressure ulcers: 33%
- Urinary incontinence: 34%
- Bowel incontinence: 13%
- UTI: 69%
- Hyperhidrosis: 15%
- Dysreflexia: 50%
- Spasticity: 44%
- Latex allergy: 10.5%
Long-term Outcomes of Pediatric SCI

- Shoulder pain 59%
- Wrist pain 27%
- Elbow pain 19.5%
- Pain other sites 51.5%
- Fractures 5%
Long-term Outcomes of Pediatric SCI

- Hypertension/heart disease: 6%
- Chronic medical conditions: 22%
- Hospitalizations past year: 22%
- Moderate-severe depression: 8%
- Substance abuse: 14%
<table>
<thead>
<tr>
<th>Condition</th>
<th>SWLS</th>
<th>CHART</th>
<th>Employment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pressure ulcers</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Spasms</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Shoulder pain</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Incontinence B/B</td>
<td>+</td>
<td>+</td>
<td></td>
</tr>
<tr>
<td>UTI</td>
<td>+</td>
<td>+</td>
<td></td>
</tr>
<tr>
<td>Dysreflexia</td>
<td>+</td>
<td>+</td>
<td></td>
</tr>
<tr>
<td>Substance abuse</td>
<td>+</td>
<td>+</td>
<td></td>
</tr>
<tr>
<td>Elbow pain</td>
<td>+</td>
<td></td>
<td>+</td>
</tr>
<tr>
<td>Wrist pain</td>
<td></td>
<td></td>
<td>+</td>
</tr>
<tr>
<td>Pain any site</td>
<td>+</td>
<td></td>
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<tr>
<td>Hospitalizations</td>
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<td></td>
<td>+</td>
</tr>
<tr>
<td></td>
<td>SWLS</td>
<td>CHART total</td>
<td>Employment</td>
</tr>
<tr>
<td>----------------</td>
<td>------</td>
<td>-------------</td>
<td>------------</td>
</tr>
<tr>
<td>Marriage</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>SF 12 Physical</td>
<td>+</td>
<td>+</td>
<td></td>
</tr>
<tr>
<td>SF 12 Mental</td>
<td>+</td>
<td>+</td>
<td></td>
</tr>
<tr>
<td>Gender</td>
<td>+</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Race</td>
<td></td>
<td>+</td>
<td></td>
</tr>
<tr>
<td>Income</td>
<td></td>
<td>+</td>
<td></td>
</tr>
<tr>
<td>ASIA motor score</td>
<td></td>
<td>+</td>
<td></td>
</tr>
<tr>
<td>Employment</td>
<td></td>
<td>+</td>
<td></td>
</tr>
<tr>
<td>CHART total</td>
<td></td>
<td></td>
<td>+</td>
</tr>
</tbody>
</table>
Implications

- Medical complications are significantly associated with key outcomes of adults with pediatric onset SCI
- Therefore, preventing medical complications may improve outcomes
Implications

Establish expectations throughout the lifespan

- Healthy
- Independent
- Employed
- Participate fully in their communities
- Satisfying lives
Relationship between parenting & demographic and injury related factors

<table>
<thead>
<tr>
<th></th>
<th>Parent n=98</th>
<th>Not a Parent n=334</th>
</tr>
</thead>
<tbody>
<tr>
<td>Female</td>
<td>66%</td>
<td>28%</td>
</tr>
<tr>
<td>Paraplegia</td>
<td>54%</td>
<td>42%</td>
</tr>
<tr>
<td>Age @ follow-up</td>
<td>33.9 (5.8)</td>
<td>32.5 (5.9)</td>
</tr>
</tbody>
</table>

*p<.05, *** p<.001
## Relationship between parenting & outcomes

<table>
<thead>
<tr>
<th></th>
<th>Parent (n=98)</th>
<th>Not a parent (n=334)</th>
</tr>
</thead>
<tbody>
<tr>
<td>SWL***</td>
<td>27.7 (5.8)</td>
<td>23.0 (7.9)</td>
</tr>
<tr>
<td>CHART physical independence*</td>
<td>93.9 (9.7)</td>
<td>91. (11.9)</td>
</tr>
<tr>
<td>CHART mobility*</td>
<td>92.2 (12.4)</td>
<td>86.8 (19.5)</td>
</tr>
<tr>
<td>CHART social integration**</td>
<td>94.9 (10.0)</td>
<td>88.9 (16.7)</td>
</tr>
<tr>
<td>CHART Occupation***</td>
<td>90.8 (21.9)</td>
<td>70.6 (32.2)</td>
</tr>
</tbody>
</table>

*p<.05, ** p<.01, *** p<.001
The challenge in caring for children with SCI

- Prevent complications during childhood
- Because of long life span of individuals with pediatric SCI
  - Identify those at risk of complications
  - Develop strategies to prevent complications throughout their lifespan
Prevention of pressure ulcers

- Need to shift responsibilities from parent to youth
- Smoking prevention
- Nutrition
- Seating systems
  - Need to change with size of patient and their needs
Prevention of upper extremity pain

• Critical role of wheelchairs
• Developmental implications
  – changing size of wheelchairs
  – different needs
  – assessing and teaching proper propulsion
• Power versus manual
  – How to save those shoulders for 60+ years in a 10 year older
Assure adequate preparation to ensure quality in adult life
The Future

- Prevention of SCI
- Wheelchair design
- Pressure ulcer prevention
- Implantable FES systems
- Robotics
- Brain Computer Interface
- Cure